FEBRUARY 1961

Metal Progress

How Empire-Reeves gets better quality steels...faster

Lee Wilson open coil annealing improves uniformity, facilitates delivery, reduces inventory at Empire-Reeves

"Improved customer service," reports Donald W. Frease, President of Empire-Reeves Steel Corporation," is just one of the assets the addition of the Lee Wilson Open Coil Annealing has given Empire."

"We can now process orders with much greater speed," he continues, "yet we can reduce our inventory in the annealing department, because—by opening the coil—hot gases can saturate the entire coil in a fraction of the time previously required. Cool-down is just as efficient.

"The quality of our product is improved because the heat quickly reaches every square inch of the surface of the steel coil. This means it receives a perfectly uniform anneal with an absolute minimum of hardness variation. Because we are handling individual coils instead of continuous strip we have wonderful flexibility. We can process short orders as easily as long runs.

"The Lee Wilson Open Coil Process thus enables us to improve our customer service and our product, and at the same time, gives us the most efficient annealing system available today," Mr. Frease concludes.

If a better product or more efficient annealing department appeals to you, why not get the last word on annealing practice. The Lee Wilson sales engineer in your area will be happy to meet with you at your convenience.

Donald W. Frease, President of Empire-Reeves Steel Corporation (center), tells J. L. Whitten, Vice President of Sales of Lee Wilson (right), and E. G. Fenton of Empire, the results of Open Coil Annealing at Empire after the first few months of operation.

Overall view of the Lee Wilson Open Coil Annealing installation at Empire-Reeves' Mansfield, Ohio, plant.

Circle 837 on Page 48-B

Lee Wilson ENGINEERING COMPANY, INC.
20003 LAKE ROAD • CLEVELAND 16, OHIO

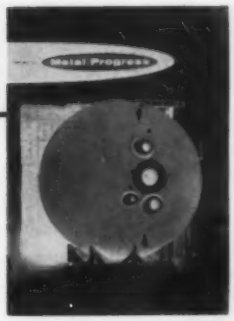
HIGH PRODUCTION ANNEALING SYSTEMS
MAKE THE BEST METALS BETTER

* ORIGINATORS AND LEADING PRODUCERS OF OPEN COIL AND SINGLE STACK FURNACES

4081

Metal Progress

February 1961 . . . Volume 79, No. 2



COVER: The photograph shows a stainless cryogenic pressure vessel emerging from the stress-relieving furnace at the Southwest Welding & Mfg. Div. of Yuba Consolidated Industries, Inc., in Alhambra, Calif. More details on its fabrication are given in the article by Warren H. Vetter on p. 88.

Technical News in Brief

New Potentiometers Use Strain-Gage Principle . . . Big Forging Press Shapes Tough Alloys . . . Outlook for Ferroalloys in 1961 . . . Aluminum Continues Uptrend in Auto Industry . . . Shear Forming Reduces Costs of Rocket Cases . . . Larger Vacuum Furnaces Go Into Operation . . . Dealing With Corrosion in Automobiles . . . Diffusion Bonding Joins Copper and Its Alloys . . . Progress in Nonmetallic Materials . . . Metals and Fabricating Method for the B-70 65

Nondestructive Testing for Management—No. 1

Why Nondestructive Testing Is Needed, by Robert C. McMaster 70

The constant increase in competition coupled with the growing demand for quality has caused manufacturing industries to concentrate on nondestructive testing as a means for reducing waste and improving reliability. A number of the general aspects, including both production and economic standpoints, to be considered in applying such testing are discussed in the article. (S13)*

Engineering Articles

Properties of Ni-Al Age Hardening Steel, by J. B. Seabrook 80

Because the nickel-aluminum steels (usually used for nitrided parts) have interesting aging properties – they do not overage despite long times at high temperature – they have been the source of much speculation and research. In this article the author concludes that the 5% Ni, 2% Al steel is potentially useful for precision gears despite its moderate impact strength. (J27d, Q-general; AY)

Chevrolet Adopts European Casting Process for Corvair Engine, Staff Report 84

Adoption of low-pressure casting for producing engine components in this country required some changes over European practice. To meet demands of high production, Chevrolet engineers built heavier machines and added automatic controls for regulating temperature, pressure and mold manipulation. (E12, T21b; Al)

Welding and Heat Treating a 60-Ton Cryogenic Vessel, by Warren H. Vetter 88

A huge storage tank for liquid oxygen (see cover) was fabricated by joining 5-in. thick segments of Type 321 stainless steel with 12,000 lb. of weld metal. The entire tank was annealed after welding. (K1, J23, SS, 2-63)

A New High-Temperature Alloy, by John Maxson 97

Devised for service above 1800° F., this new nickel-base alloy, termed RA-333, contains 25% chromium, and 3% each of molybdenum, cobalt, and tungsten. Its excellent creep-rupture properties, low coefficient of expansion, and good oxidation resistance have made it useful for critical parts in heat treating furnaces. (Q-general, 2-62, W27p; Ni-b, SGA-h)

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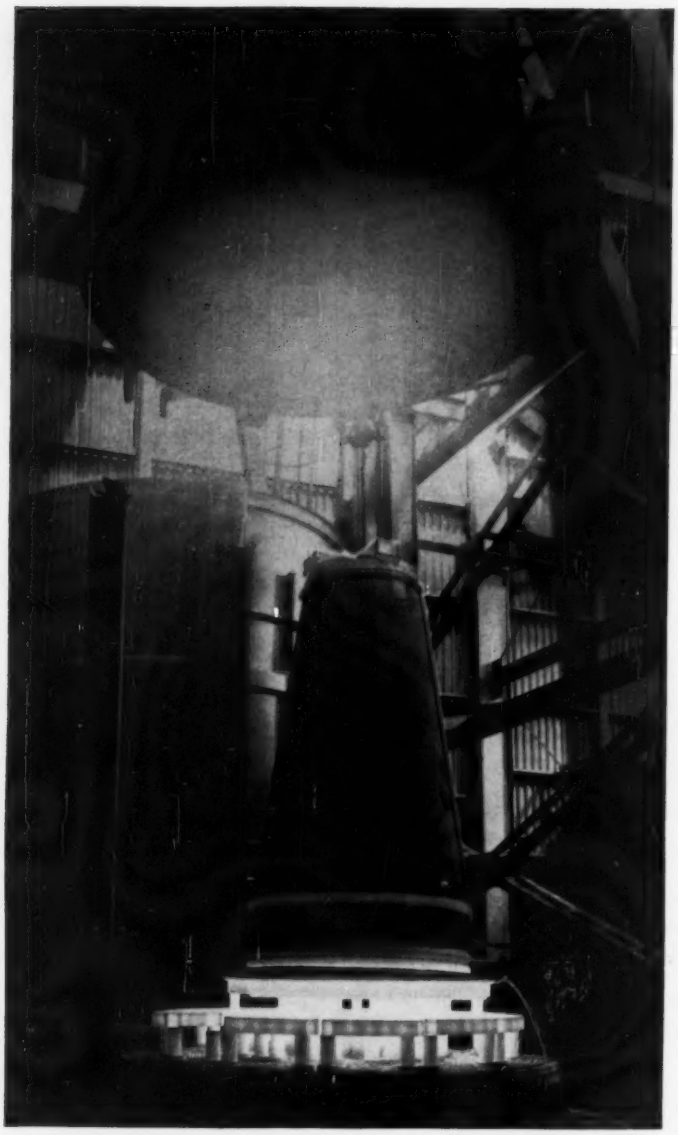
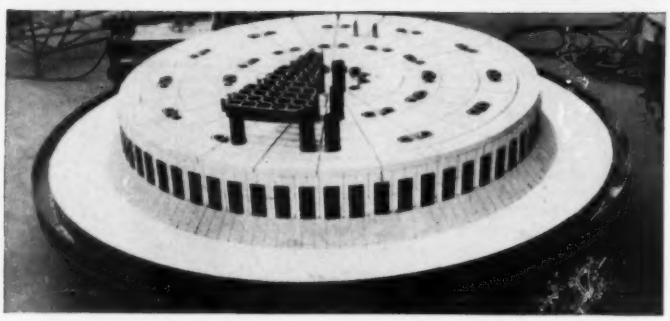
**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

New Alloy Supertherm* proves itself in 2300 degree fahrenheit brazing furnace





Supertherm hearth grid segment during furnace construction.

In a brazing furnace for the thrust chambers of rocket engines at Rocketdyne Division of North American Aviation, Inc., Canoga Park, Cal., a Supertherm furnace hearth grid assembly is operating at a temperature of 2300° F. The grid in a furnace built by the General Electric Company's Industrial Heating Department at Shelbyville, Ind., supports the engine parts during a brazing cycle of from five to eight hours with a maximum temperature of 2300° F. At this extreme temperature and under severe conditions of thermal fatigue created by the brazing cycle, *the Supertherm grid has performed successfully over one year.*

Supertherm is Electro-Alloys' new alloy for the 1800 to 2300 degree fahrenheit range. The composition of Supertherm is 26% chromium, 35% nickel, and is strengthened and stabilized with cobalt and tungsten. For technical information about the composition, physical and high temperature properties of Supertherm, fill out and return the coupon or contact your local Electro-Alloys representative.

*Supertherm is a patented alloy.

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AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION · Elyria, Ohio

Circle 868 on Page 48-B

Metal Progress

Modern Plant Produces Oxygen-Free Copper, by Dragoslav Janicijevic 112

The entire output of oxygen-free copper at this Yugoslav plant is cast as wire bars in a continuous casting machine. Contamination of molten cathode copper is prevented by melting and holding the metal in enclosed induction furnaces and by protecting it with an atmosphere composed of carbon monoxide and nitrogen. (C5q; Cu-a)

Advances in High-Temperature Materials

How to Forge Astroloy, by John Luchok 91

Large forgings, up to 1000 lb. in weight and 35 in. in diameter, are now being made of this alloy, the newest member of the nickel-base superalloys. Continuing research is expected to make the alloy even more useful as time goes on. (F22; Ni-b, SGA-h)

Carbides in Waspaloy, by J. F. Radavich and W. J. Pennington 94

The predominant carbide in this superalloy is MC, which contains titanium, nickel, molybdenum and zirconium. Aging breaks down this phase, and $M_{23}C_6$ forms at grain boundaries and within the grains. (M26r; Ni-b, SGA-h)

Heat Processing of Stainless Steels

Heat Treating and Sintering Stainless in an Atmosphere, by Bernt A. Ruediger 101

Hydrogen and dissociated ammonia are often used for protective atmospheres when bright annealing or sintering stainless steel parts. This article discusses the characteristics of such atmospheres, and describes the various types of furnaces and gas generators which can be used. (J2k, H15q; SS)

Vacuum Furnaces Are Versatile, by H. W. Westeren 106

For tricky heat treating applications – brazing stainless steel parts, for example – vacuum "atmospheres" can be very useful. This article details the characteristics and applications of vacuum heat treatments. (J2k, 1-73)

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Cooling Transformation Diagrams for A.I.S.I. 9260 and 4047, by R. C. Hess and D. J. Blickwede 100-B

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permits 360° radiography and can be coned down to a single beam . . . yet weighs only 136 lbs.

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Weight: 41 lbs.
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Also included: 25′ and 60′ connecting cables and individual carrying cases.

Westinghouse

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PRESS BREAKS

Over the years the editors of *Metal Progress* have attempted to limit the length of articles so as many topics as possible could be considered in a single issue – necessary in view of the scope and complexity of the metallurgical field – but also because we instinctively felt that a very long paper would be disregarded by a busy man. This last belief has been shaken by listing the requests for reprints which we have received since January 1960. For example, reprints of a 9½-page article "Refractory Metals for Air and Space Vehicles" by Consulting Editor Gassner – almost a record for length – were requested by 106 readers. (The number of requests for reprints of *all* articles in that November issue totaled 603.)

This led us to study the results of the readership surveys made quarterly since 1953 by the Eastman Research Organization. These issues contained 253 articles in the main editorial "block", varying from one to nine pages in length. It turned out that average readership had no relationship to length of articles in *Metal Progress*. In other words, the many ASMembers interviewed who read the articles completely, or who scanned the articles sufficiently to remember the fact, did so irrespective of length. In other words, "total traffic" is substantially the same, no matter how long the article.

Maybe the best way to insure high readership is to select topics of wide interest, currently newsworthy, and then present the material in a clean, attractive manner, using as much space as is necessary to present the facts. This is our objective.

Do ASMers Read "New Literature"?

An editor's life is full of surprises. For example, in preparing over 200 New Literature items each month we are, of course, interested in knowing the value of this department to our readers. A recent survey of reader response to New Literature gave us a very clear answer to the above question. Last July, the Timken Roller Bearing Co. offered an unusually good booklet, "Practical Data for Metallurgists", which drew a total of 1139 requests – a record for this department. The heartening conclusion is: People do read the New Literature section and they respond in impressive numbers when good material is offered.

Speaking of records, we recently ran across a phrase in a news release which deserves the 1960 "G.A." (galloping adjective) prize for length. Describing a new machine, the over-zealous public relations man wrote " . . . this [Model 000] Double Drive Gantry Three Dimensional Electro Hydraulic Trace Universal Contour Profile Milling Machine . . .". Fifteen adjectives! Count 'em! Leaves one breathless but informed? ! !

Who Belongs to the ASM?

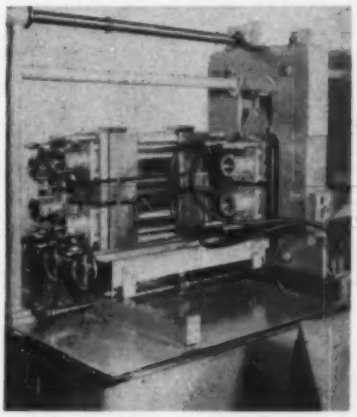
A recent questionnaire sent to every 15th name on the A.S.M. membership list indicates the following distribution as to title or function: Administration 11.2%, Engineering 65.1%, Production 22.4%, Others 1.3%.

Almost exactly half of those in "Engineering" had such titles or functions as metallurgical engineer, metals engineer, materials engineer and the like. Forty percent of all members are at plants or with firms having 2000 employees or more.

THE EDITORS

NEWS FROM

LOMA



This heavy-duty, high-precision 2-high/4-high Combination Rolling Mill was recently installed at the new Fuels Technology Center of the Argonne National Laboratory. The outstanding feature of the new machine is its complete enclosure in a controlled atmosphere glovebox to allow the processing of alpha-active, pyrophoric materials, such as plutonium.

To facilitate remote control operation within the glovebox enclosure, the mill is equipped with a mechanized roll changing device comprising a roll storage car, three slideways to carry three roll assemblies, quick-disconnect screwdowns and universal spindle supports. The entire roll assemblies are readily moved into or out of the mill by turning a handwheel and are cross-transferred by moving the car along the face of the mill. Thus, complete roll changes can be performed in a few minutes without undue effort.

The new LOMA rolling mill may be operated in either a 6 in. x 8 in. 2-high set-up or a 1½ in. & 6 in. x 8 in. 4-high set-up. The 2-high arrangement is used for either hot or cold breakdown rolling of plate and sheet, and grooved rolls are also available to process rounds from 1 in. to ¼ in. diameter. In the 4-high set-up strip is cold finish rolled to gauges as thin as .002 in.

The mill is furnished with high-strength steel housings, twin-handwheel wormdrive screwdowns, universal joint spindles, herringbone gearing, and a 15 h.p. reversing variable-speed drive. The roll necks are mounted in super-precision needle roller bearings having a total separating force capacity of 175,000 lb. The bearings are continuously lubricated by an oil circulating system.

Special cartridge heating elements are mounted in the rolls to prevent undue chilling of the materials being hot worked. The heating elements are fed with current through slip rings and brushes mounted at the outboard side of the mill.

LOMA

MACHINE MFG. CO., INC.

114 East 32nd Street

New York 16, N. Y.

Circle 870 on Page 48-B

How would you anneal these 5 types of alloy wire?

The various types of alloy wire in this photograph are manufactured for specialized applications by the Riverside-Alloy Metal Division, H. K. Porter Company, Inc. They range from stainless steel, for aircraft industry use, to monel metal and an iron-nickel-cobalt alloy with thermal expansion characteristics suitable for sealing to hard glasses. Annealing temperatures range from 1450 to 2150 F, close control being necessary to maintain wire quality, measured by elongation, grain structure and tensile strength. The wire is annealed continuously—normally in a disassociated ammonia atmosphere.

Experience has proved that electric furnaces equipped with GLOBAR® silicon carbide heating elements offer the cleanliness and capability for precise temperature control needed in this operation. The GLOBAR elements easily provide the maximum 2150 F heat—in fact, can be used with safety to above 2750 F. One of the furnaces used, with 13½" thick walls of refractory insulating brick, has required no maintenance of the lining over a 10-year period—pointing up the mild conditions to which insulating brick are subjected with this type of heat. With the low heat capacity of the insulating brick, it is possible to drop temperatures rapidly in going from the high to low end of the range.

The many advantages of heating with GLOBAR elements, as illustrated in this particular case, often more than cancel out possible differentials in Btu costs between electricity and other fuels. Why not investigate with your furnace builder—or write to Refractories Division, Globar Plant, Dept. MP-21, Niagara Falls, N. Y.

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- Elements 4" to 105" in length.
- For greater economy in heat treating, brazing, forging, melting and sintering.

CIRCLE 871 ON PAGE 48-B

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Typical Induction Heating Applications

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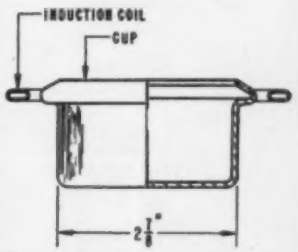
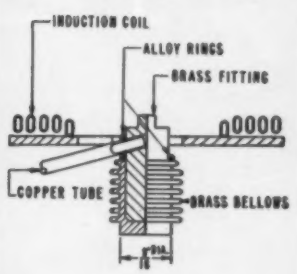


Flanges of cups made from type 321 stainless steel are selectively annealed by induction heating prior to further forming. Flanges are heated to 2000° F and water quenched. Single-turn coil restricts heating to the flange area.

Our engineers will process your work samples and return the completed job with full data and recommendations without cost or obligation.

Bellows Assembly Brazed



Brass bellows and copper tube are simultaneously silver-alloy brazed to a brass fitting by induction heating. Plate-type induction coil produces proper temperature at each joint.

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Electr-O-Line
CLOSE
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PWR ON
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Electr-O-Pulse
LOAD ON
CYCLE TIME
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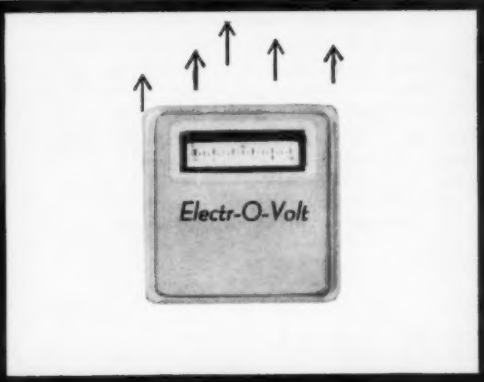

Electr-O-Volt

Three ways to get peak performance from your furnaces!

1. Electr-O-Line Control Unit for position-proportioning control with reset and rate action
2. Electr-O-Pulse Control Unit for time proportioning control with reset and rate action
3. Electr-O-Volt Control Unit for current-proportioning control with reset and rate action

These new Honeywell three-mode control units can actually improve the performance of your furnaces by providing the exact temperature that's needed. They include features that cannot be matched:

Smooth three-mode control with extra-wide band adjustments. You can adjust the proportional band up to 500%; reset action from 0 to 100 repeats per minute; and rate time from 0 to 10 minutes. Proportional band can be readjusted without upsetting the process. Special rate circuit minimizes overshoot in batch processes and during startup. Auto-man switching on all units is bumpless.

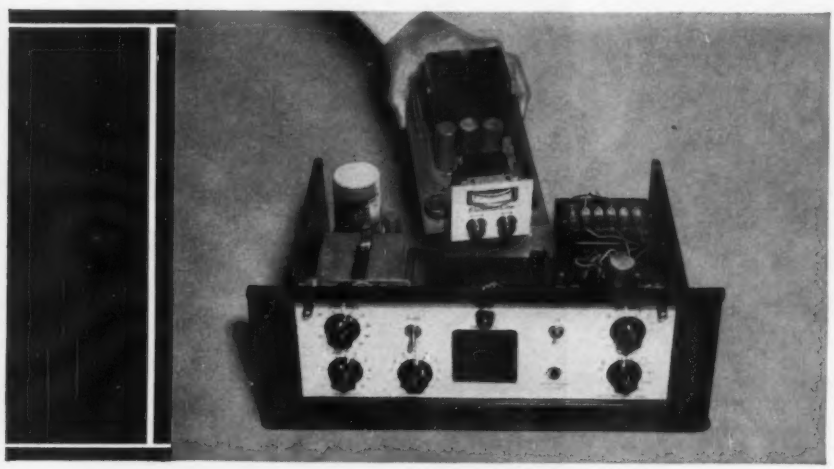
Modular construction with interchangeable control output sections. Modular plug-in construction is used throughout. Amplifier and power supply sections are the same for all three units. Only the control output section changes. Interchangeability of this section simplifies stocking and servicing.

ElectroniK Strip Chart, Circular Chart, and Circular Scale Controllers are used with Electr-O-Line, Electr-O-Pulse, and Electr-O-Volt units. They are integrally mounted, simplifying panel cutout and reducing wiring costs.

For more complete details on these and other types of furnace controls, contact your nearby Honeywell field engineer. He's as near as your phone. MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

H HONEYWELL *First in Control* SINCE 1885



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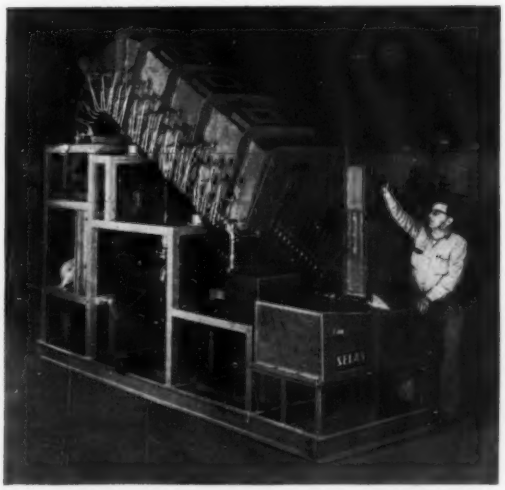
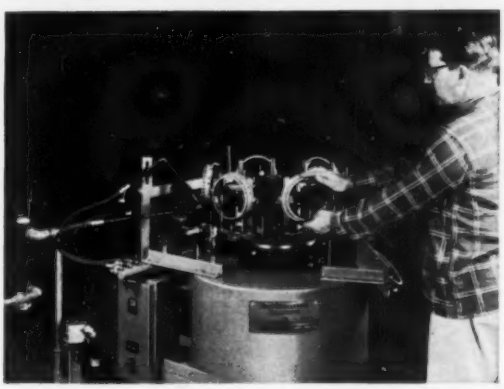
NEW SLANTS ON HEAT PROCESSING FROM SELAS

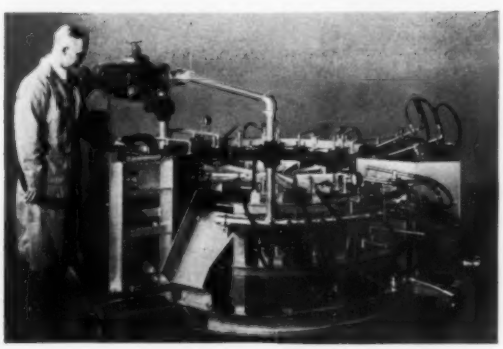
here's how industry cuts costs product quality with Selas



FORGING *Continuous unit fits compactly into production line to heat alloy steel bars for forging into C-shaped rail anchors. Production is synchronized with the forging bulldozer, up to 620 bars per hr. Inventory of work-in-process is ⅓ to ¼ of previous equipment . . occupies 20% less floor space . . reduces scale 95%. Precise heating assures consistently uniform grain structure and hardness.*



BRAZING *Compact machine automatically silver brazes Carboloy cutter to stainless steel shredder ring used in garbage disposal units. Precise fixturing, localized high-speed heating and automatic unloading permits one operator to produce up to 200 pieces per hr. . . Completely shop-assembled at Selas, unit was installed in customer's plant, ready for production operations, within hours.*



SELECTIVE HARDENING *End portions of brake shoe webs are hardened to create a more durable product. An indexing conveyor brings the two ends of webs under Duradiant burners. Designed for automatic loading, the machine heats, quenches, tempers and mechanically unloads the selectively-hardened work pieces. Service life of webs has been extended, costs have been reduced.*

. . . improves heat processing equipment

ANNEALING *Six-station dial conveyor automatic machine anneals a narrow band on stainless steel auto hub caps. Workpieces rotate above burners, bringing 2-in. wide band to 1800°F. in 30 sec. Production is 600/hr. Only 6 ft. 6 in. in diam., unit is located directly in the press shop production line.*

The installations on these pages demonstrate how Selas automatic heat processing equipment

- cuts operating costs
- increases production rates
- minimizes in-process inventory
- reduces labor requirements
- saves valuable floor space
- improves product quality

Specifically designed and custom-built to meet your individual production requirements and job specifications, Selas heat processing equipment employs time-proven standardized engineering features for longtime operating dependability and minimum initial investment. Problems usually associated with divided responsibility are avoided since Selas starts-up and services every machine it designs and builds.

Selas automatic or semi-automatic heat processing equipment can help you produce better products at lower costs. At your convenience—without obligation to you—a Selas field engineer would welcome the opportunity to survey your requirements.

For this free, personal service, or for literature on any of the heating operations shown here, write Mr. W. B. Troupe, General Industry Division.

SELAS CORPORATION OF AMERICA
32 Dreshertown Road, Dresher, Pa.

EUROPEAN SUBSIDIARY: Selas Corporation of America, European Div., S. A., Pregny, Geneva, Switzerland. INTERNATIONAL REPRESENTATIVES AND LICENSEES: CAMBODIA, FORMOSA, KOREA, LAOS, VIETNAM—Cosa Export Co., Inc.; JAPAN—International Machine Co., Ltd., Tokyo; FRANCE—Societe Exploitation de Produits Industriels, Paris.

SELAS

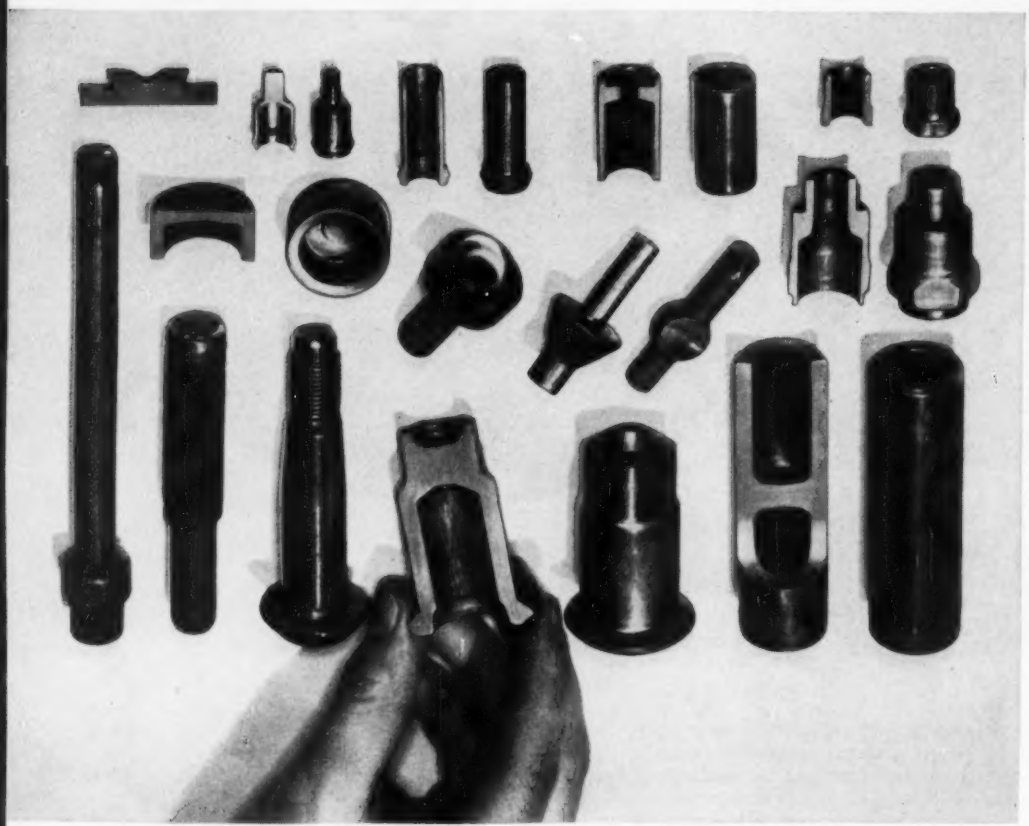
HEAT AND FLUID PROCESSING ENGINEERS

DEVELOPMENT
•
DESIGN
•
CONSTRUCTION

CIRCLE 874 ON PAGE 48-8

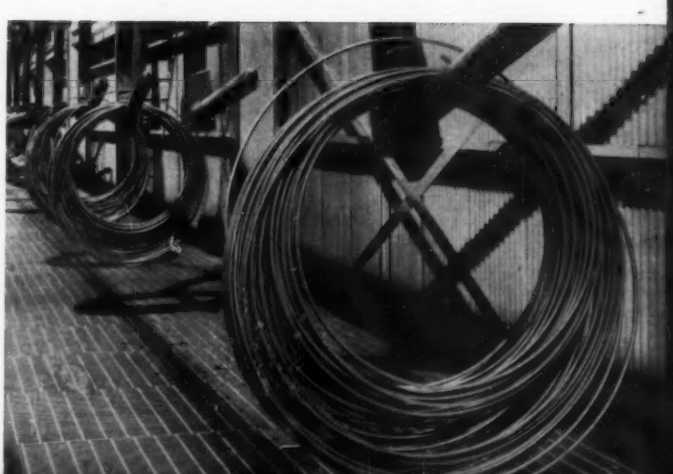
From the industry's most advanced bar mill...

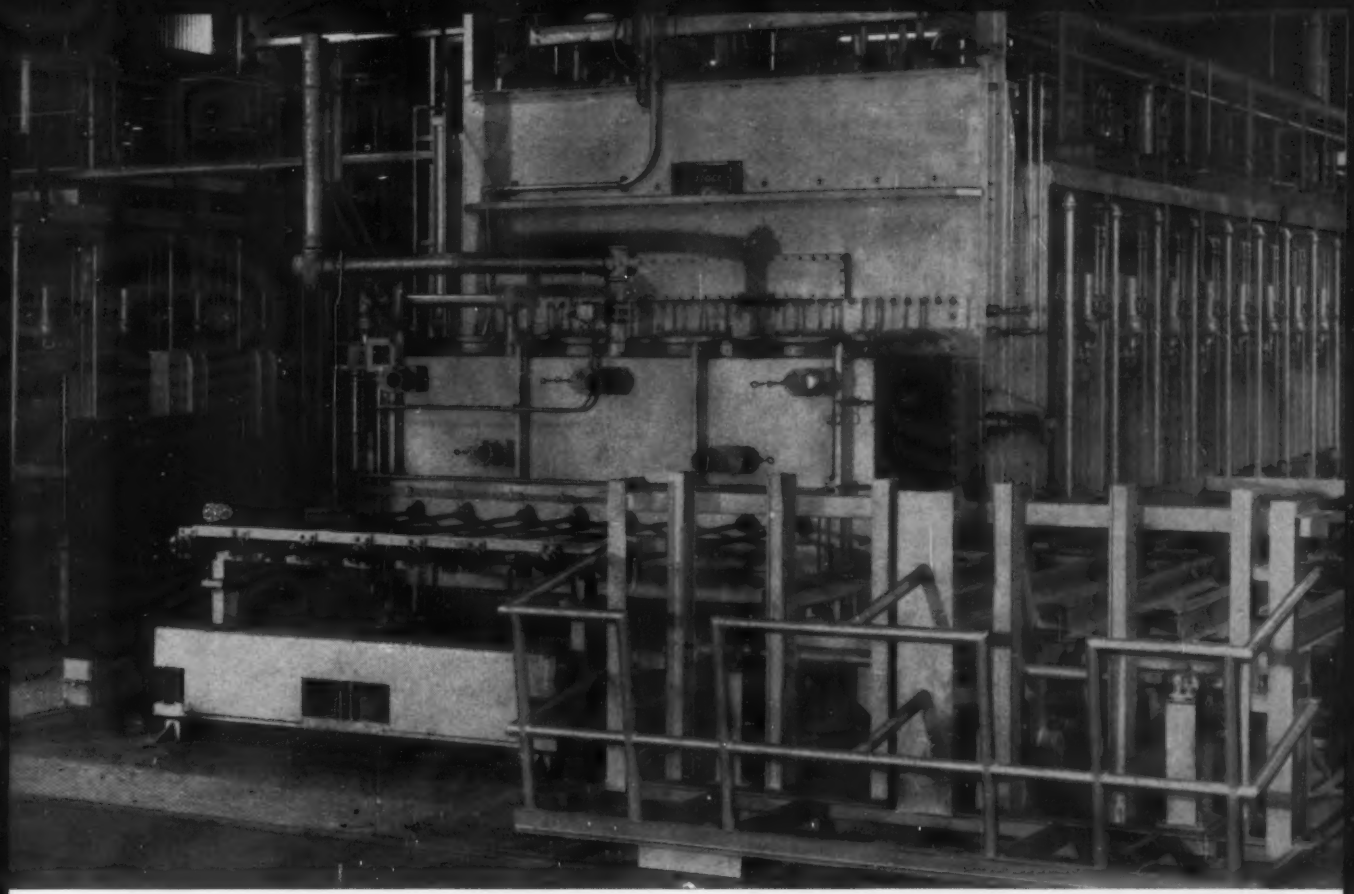
REPUBLIC STEEL FOR COLD EXTRUSION



THE COLD EXTRUSION PROCESS virtually eliminates raw material waste. Standard equipment is available so that retooling costs are not excessive. Bars produced on this 11″ mill have denser, more uniform structures because they undergo more hot work. A larger than usual billet—3″ or 4″ square—is rolled to finished products of standard sizes.

HEAVIER COILS weighing up to 1600 pounds mean fewer fabrication changeovers, less scrap loss. High speed coilers handle the complete range of bars produced (⅜″ to $^{29}/_{64}$″—700 to 900 pounds; ⅝″ to 1½″—1400 to 1600 pounds). Each coil undergoes ultra-precise inspection to assure conformance to specifications, then is double banded for safe, efficient handling.





Annealed, normalized, or spheroidized to your precise specifications

Atmosphere controlled, continuous annealing furnaces give Republic's new 11″ bar mill maximum annealing capacity. Steel for cold extrusion or cold heading can be furnace-treated, finished, and delivered to your precise specifications. The mill has facilities to pickle, oil, lime, or phosphate coat.

Depending on the nature of your product, you may find it more advantageous to use steel in the cold finished form. Either way, our metallurgists will help you select and apply the most economical bar product—carbon, alloy, or stainless—capable of meeting your requirements.

Republic Steel is the nation's largest producer of steel for cold extrusion. For complete data, contact your nearest Republic representative or mail the coupon below. Please indicate if you would like a metallurgist to call.

Strong, Modern, Dependable

REPUBLIC STEEL

World's Widest Range of Standard Steels and Steel Products

CIRCLE 875 ON PAGE 48-8

REPUBLIC STEEL CORPORATION
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1441 REPUBLIC BUILDING • CLEVELAND 1, OHIO

Please send more information on:

☐ Steel for cold extrusion ☐ Steel for cold heading
☐ Steel for cold forging ☐ Have a metallurgist call

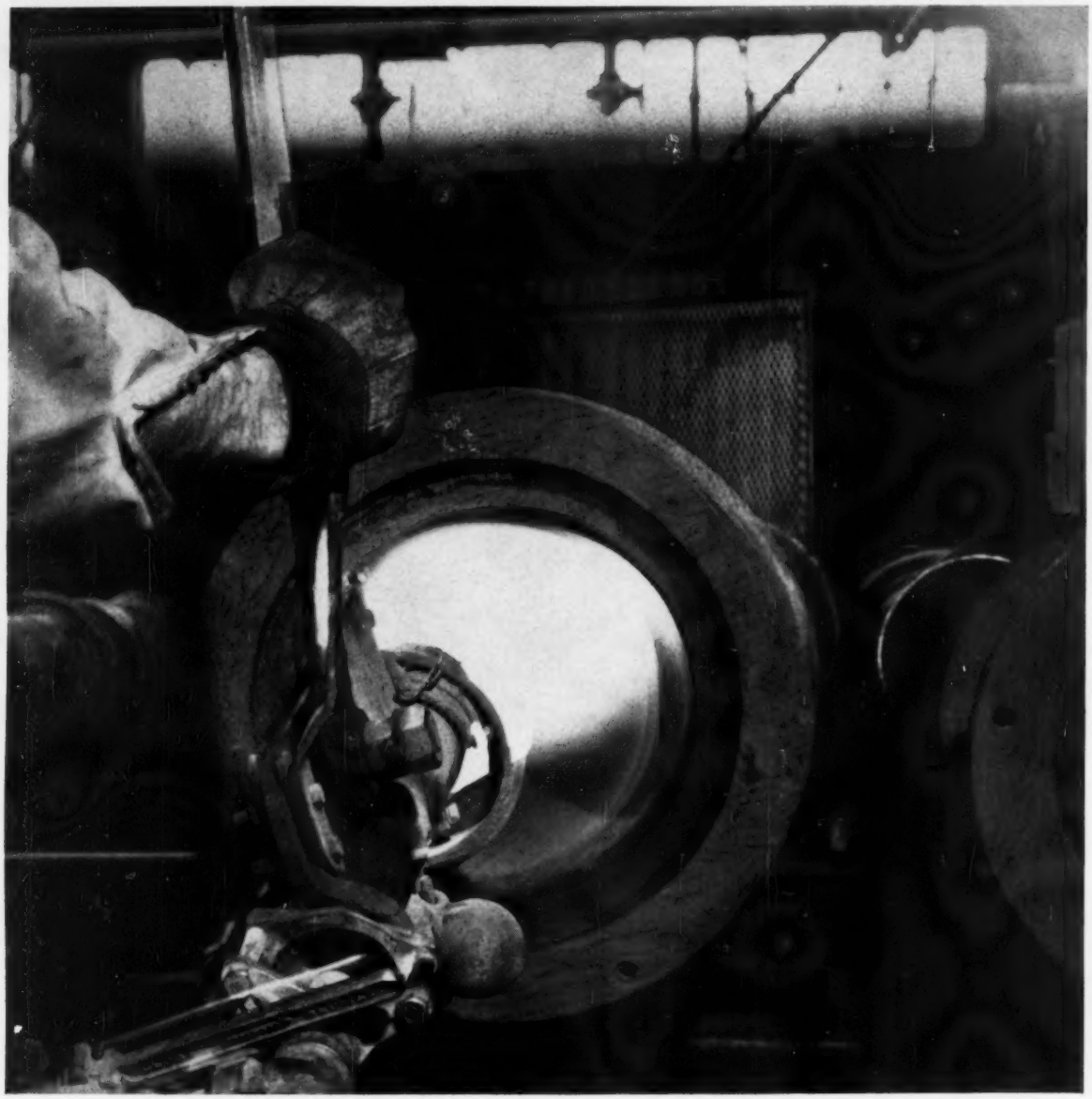
Name_____ Title_____

Company_____

Address_____

City_____ Zone____ State_____

Intense heat from four Gas-fired torches skin dries pipe molds in as little as 2 minutes, after ramming and facing with a blacking material.



Only GAS provides the clean, uniform heat needed to skin dry pipe molds! Millions of BTU's of clean, uniform heat are required every hour by Warren Foundry & Pipe Division of Shahmoon Industries, Inc., Everett, Massachusetts, to skin dry its pipe molds.

Only Gas provides this volume of heat without any problems of shipping and storage. That's why Warren Foundry chose Gas to solve this large scale heating problem. And as plant engineer William Mitchell says, "We chose Gas over other fuels because of its cleanliness and uniformity of heat value."

For information on how Gas can help you with your production problems, call your Gas Company's Industrial Sales Engineer. He'll be glad to discuss with you the economies and outstanding results you get with the clean, uniform heat of Gas, and modern Gas-fired industrial equipment. AMERICAN GAS ASSOCIATION

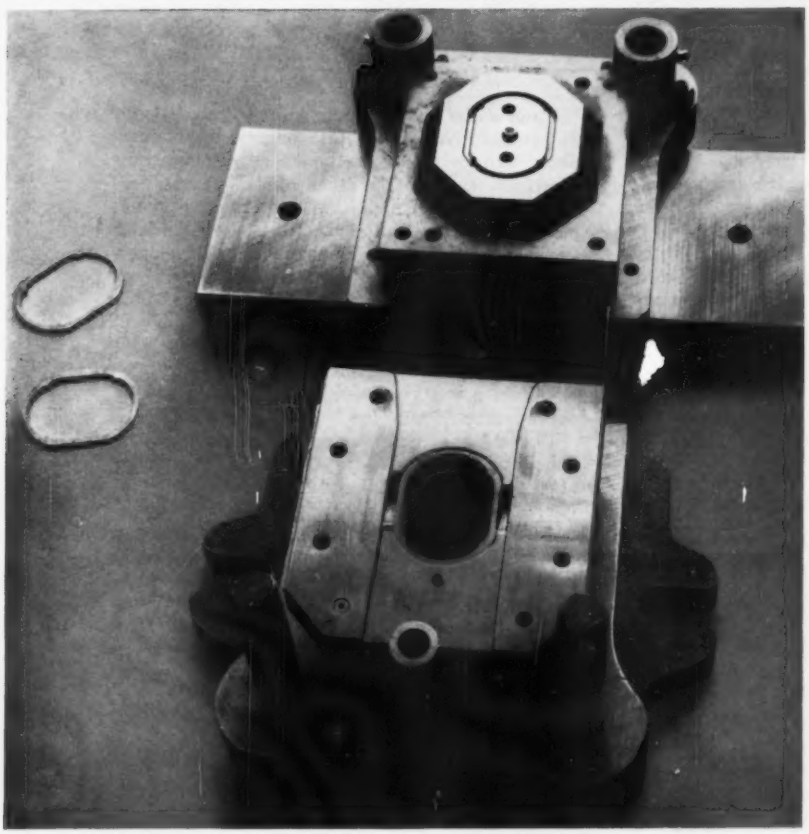
FOR CONTROLLED INDUSTRIAL HEATING

. . . GAS IS GOOD BUSINESS!

CIRCLE 876 ON PAGE 48-B

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.



Blanking die output up 300 per cent when they changed to Bearcat tool steel

Bearcat is the major grade of tool steel in this compound die which blanks and pierces an automotive piston strut at Art Stamping, Inc., Cincinnati. The die, hardened to Rockwell C57-59, was fed slugs of .075-gage C1035 hot-rolled steel. With the tool steel formerly used, an average of 115,000 pieces was produced. But with the change to Bearcat, more than 500,000 pieces were obtained before die failure. That's really cutting costs!

Bearcat is our super grade of shock-resistant tool steel. And it has plenty of wear-resistance for long runs. An air-hardening grade, it minimizes quenching hazards and distortion in heat-treatment.

Bearcat is ideal for blanking and forming dies, hot headers, shear blades, punches, and die-casting die inserts. In fact, it's right at home in any application calling for unusual toughness.

If you would like to put Bearcat to work in your shop, get in touch with your Bethlehem tool steel distributor. He has Bearcat in stock, in a wide size range. Give him a call today.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Lehigh H Still the Best Non-Distorting Tool Steel

Many of today's new tool steel grades are air-hardening types, such as Bethlehem's Bearcat and Air-4. Tests on these new air-hardening grades invariably show relatively low distortion in heat-treatment. Measurements on small test pieces, or on specific tools, often show size changes, resulting from hardening, of about .0002-.0004 in. per in. But due to over-enthusiasm, such results are often interpreted—and incorrectly—to indicate that the grades themselves are the long-sought "non-distorting tool steels."

However, tests on specimens of a variety of sizes and shapes show that individual dimension changes vary from zero to about .001 in. per in., averaging .0006-.0007 in. per in.

Production tools made from all medium alloy air-hardening tool steels will show low distortion to a degree which may eliminate many problems encountered with oil- or water-hardening tool steels.

When considering the low distortion of these steels, remember that Lehigh H (AISI D-2) has even lower distortion. Furthermore, the distortion resulting from heat-treatment of tools made of Lehigh H is both predictable and controllable, even to zero distortion, if required. This can be accomplished by the austenite-martensite balance method described in Bethlehem's tool steel catalog.

Such medium alloy air-hardening tool steels as Air-4, A-H5, and Bearcat are good performers on distortion. But Lehigh H is the best of all.

TYPICAL ANALYSES

	C	V	Mn	Cr	Mo	Pb
Air-4	0.95	—	2.00	2.20	1.10	0.25
A-H5	1.00	0.25	0.60	5.25	1.10	
Bearcat	0.50	—	0.70	3.25	1.40	
Lehigh H	1.55	0.90	—	11.50	0.80	

ANNOUNCING A NEW PUBLICATION...

at Reduced Subscription Rates for American Society For Metals Members

The first, or "collector's" edition of a new American Society for Metals publication will be available this coming **February, 1961.** The new publication is a magazine well in keeping with the ASM tradition of editorial excellence. The new magazine is titled, "Metals Engineering Quarterly." ASM members may subscribe at reduced rates.

The content of the new quarterly will include technical papers presented at metals engineering programs developed and supervised by the ASM Metals Engineering Program Committee.

The new publication will serve as a sister publication to the well-known and respected ASM Transactions. But whereas the ASM Transactions is published to carry technical papers of a scientific nature, the Metals Engineering Quarterly will present technical papers of a considerably more practical nature.

For example, the February issue includes the following papers in its 112 pages:

HIGH-TEMPERATURE PROPERTIES OF RENÉ 41 AND ASTROLOY

PROPERTIES OF GRAY AND DUCTILE IRONS

FRACTURE TOUGHNESS OF STEEL FOR PRESSURE VESSELS

FAILURE OF STEAM-WATER HEAT EXCHANGERS

PROCEDURES FOR HIGH-TEMPERATURE FAILURES EVALUATION

APM ALLOYS

STRENGTHENING LOW-ALLOY STEELS BY DEFORMING AUSTENITE

REFINEMENT OF ALUMINUM-21% SILICON CASTING ALLOYS

Each of the above papers was presented at the recent 42nd National Metal Congress in Philadelphia. Future issues of the Metals Engineering Quarterly will contain other MEPC papers presented at the Philadelphia Congress, at regional metal congresses such as the 1961 Western Metal Congress, and from regional programs developed through MEPC throughout the year in various parts of the country.

The Metals Engineering Quarterly has no counterpart in ASM publications and has been created to offer ASM members the opportunity to obtain practical, useful information on a wide variety of subjects at the least cost possible.

The Metals Engineering Quarterly will be issued in February, May, August and November of each year. The magazine will be 8½ x 11 in size. Binders will be available for the four Quarterly issues. ASM members may subscribe at a rate of $6.00 per year. (Non-members, $10.00 per year.)

ASM members can now build one of the most up-to-date, extensive and authoritative libraries at an extremely small investment.

Please enter your subscription by using the coupon below. You may enclose your check or request to be invoiced at a later date.

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Please enter my subscription to the **Metals Engineering Quarterly,** at **$6.00 per year. ($10.00 for non-members)**

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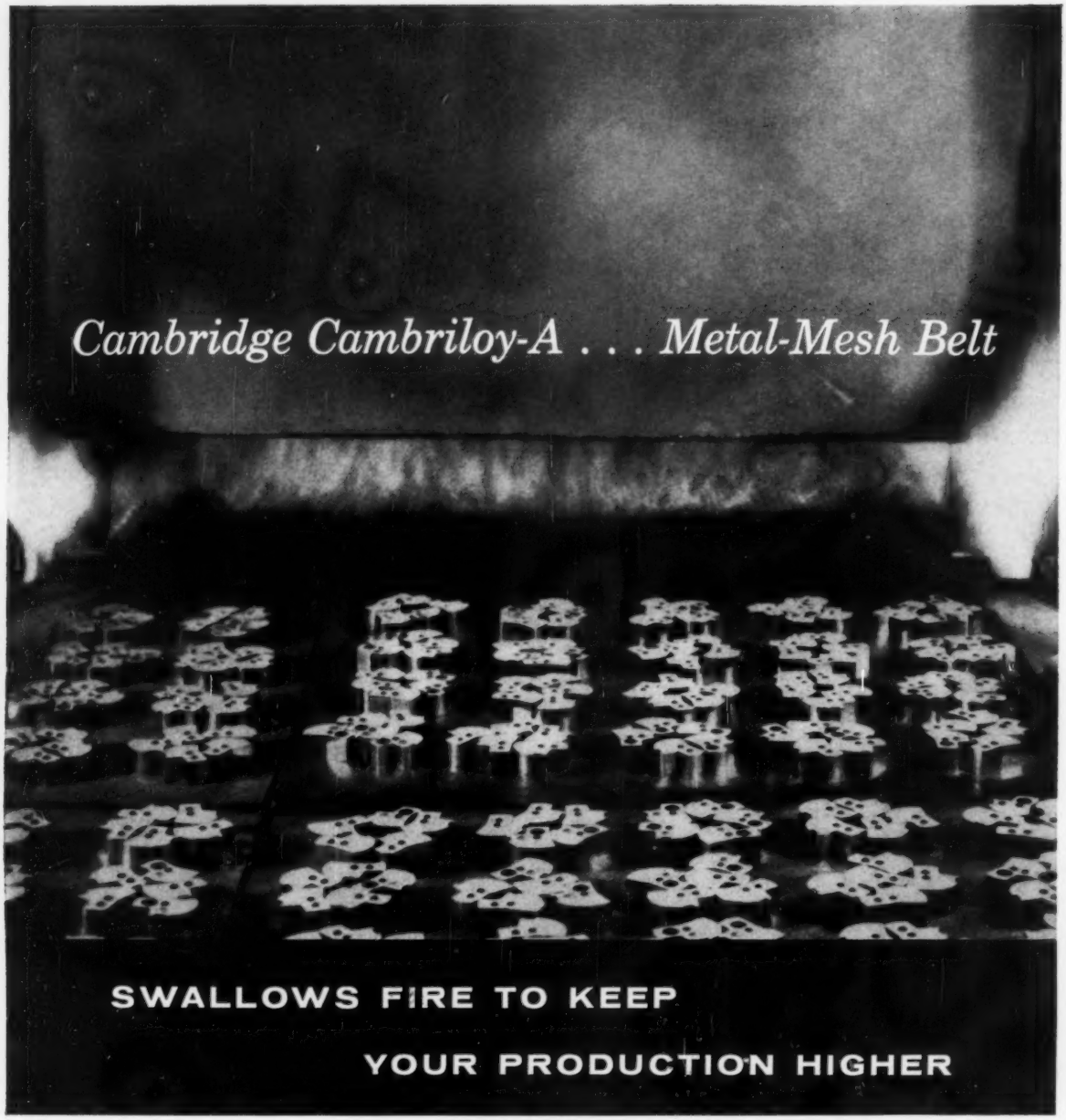
Subscriptions will be accepted and fulfilled according to postmarks. It is suggested that you act promptly to insure receipt of the Metals Engineering Quarterly from the first printing.

PICTURE
OF A WELDOR
REACHING FOR
SATISFACTION

HARNISCHFEGER
Milwaukee 46, Wisconsin
P&H
WELDING PRODUCTS DIVISION

Circle 790 on Page 48-B



2100° F. sintering temperatures are no place for weakling belts. That's why so many sintering installations select Cambridge Belts made of Cambriloy-A alloy. They are specifically designed for high strength in high temperatures and resistance to murderous furnace oxidation atmospheres . . . build to give continuous month after month service and peak production with little or no maintenance.

There is a complete line of Cambridge Belts in special and standard metals and alloys to meet your specific requirements—custom built in any one of nine basic weaves to insure the most efficient processing.

Experienced Cambridge Field Engineers—experts in their field—are available to discuss your needs and help you select the belt best suited to your operations. Or, they can offer you sound advice on the installation, operation and maintenance of your Cambridge Belts. Talk to your Cambridge man soon. He's listed in the Yellow Pages under "Belting, Mechanical". Or, write for free 130-page reference manual.

The Cambridge Wire Cloth Co.

Department B • Cambridge 2, Md.

Manufacturers of Metal-Mesh Conveyor Belts, Flat Wire Conveyor Belts, Wire Cloth, Wire Cloth Fabrications, Gripper ® Metal-Mesh Slings

Circle 791 on Page 48-B

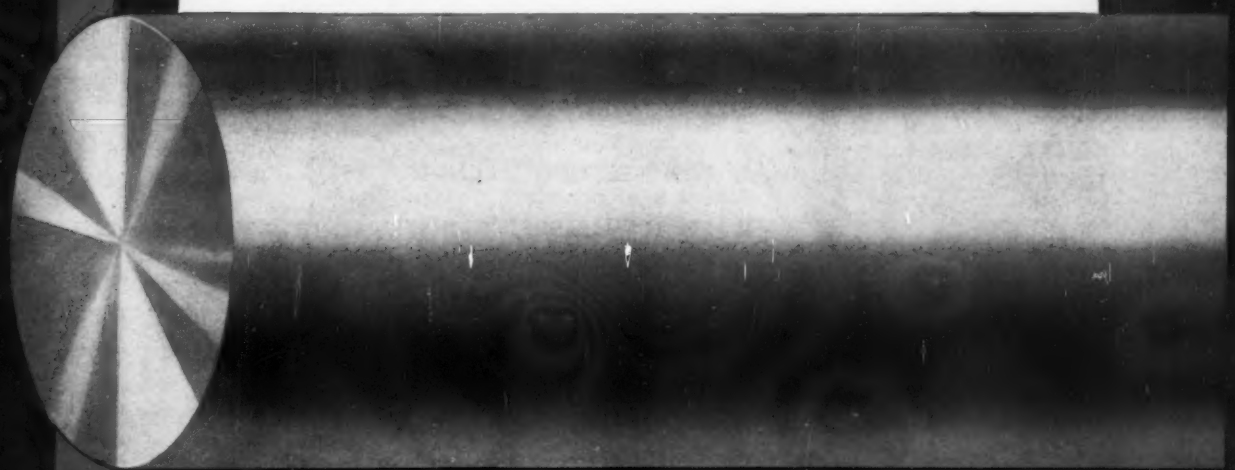
Application tested! Proved!

WHY HEAT TREAT PARTS? use e.t.d. 150

elevated temperature drawing (150,000 psi tensile)

ALLOY STEEL BARS

- **e.t.d. 150 Alloy needs no heat treating!**
- **e.t.d. 150 Alloy has 150,000 psi tensile guaranteed! (Rockwell C32 minimum)**
- **e.t.d. 150 Alloy machines better than heat treated alloy steels!**



Here are cost-reducing advantages

(1) Heat treating problems, costs (and secondary operations) are eliminated. (2) "e.t.d." 150 machines better than heat treated in-the-bar alloy steels. (3) Tool life and finish are excellent. (4) No quench cracks or distortion from heat treatment. (5) "e.t.d." 150 has exceptional strength and hardness uniformity across the bar. (6) End cost of parts is greatly reduced.

Use this coupon to request Helpful Data Bulletin 22.

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Manufacturers of STRESSPROOF®, FATIGUE-PROOF®, and a complete line of cold-finished steel bars.

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Available from your Steel Service Center

Circle 792 on Page 48-B

Up Another 1000° to

5000°F

Complete high temperature instrumentation by RIEHLE® *"warms up" to new research challenges*

CREEP AND STRESS RUPTURE TESTING MACHINES

HYDRAULIC FATIGUE TESTING MACHINES

HYDRAULIC UNIVERSAL TESTING MACHINES

UNIVERSAL SCREW POWER TESTING MACHINES

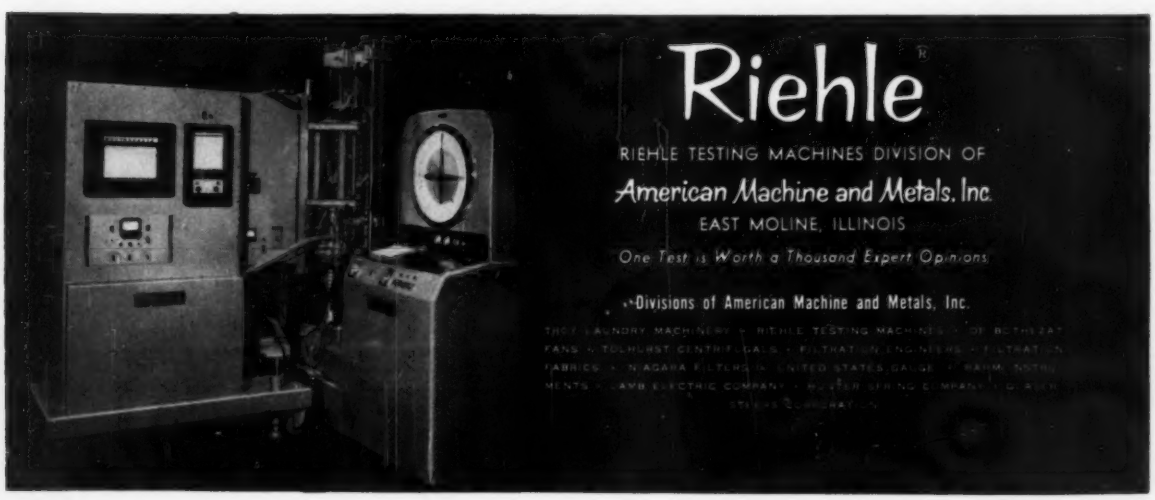
Typical arrangement of Riehle Testing Machine with High Temperature Vacuum Furnace Console for up to 5000° F.

Now RIEHLE offers you ready-to-operate systems for testing physical properties of materials up to 5000° F, 4000° F, 3000° F and other lower temperatures incorporating all of these components:

1. **BASIC TESTING MACHINE**
2. **STRAIN MEASURING INSTRUMENTATION** for atmosphere, controlled atmosphere furnaces and vacuum furnaces.
3. **COMPLETE HIGH TEMPERATURE ACCESSORIES** including furnaces, temperature controllers, vacuum pumps, extensometers and a complete line of related instrumentation.

RIEHLE is your ONE source for complete strain measuring instrumentation from room temperature snap-on extensometers to dual range instruments and highly sophisticated vacuum furnace extensometers.

Save time on vital projects. Contact RIEHLE now about your requirements for physical testing at elevated temperatures. Write Dept. MP-261.


Riehle
RIEHLE TESTING MACHINES DIVISION OF
American Machine and Metals, Inc.
EAST MOLINE, ILLINOIS
One Test is Worth a Thousand Expert Opinions
Divisions of American Machine and Metals, Inc.

Circle 793 on Page 48-B

NEW PRODUCTS

Nonferrous Metals

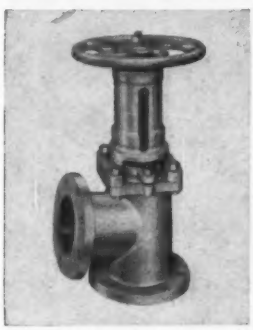
High-Conductivity Plate

Large rolled plates in two resistance welding alloys – Ampcoloy 95 and 97 – meet RWAA Class II and III specifications for use as backup plates and bars, welding dies, and die inserts. Depending on thickness, widths range from 48 to 60 in.; lengths range from 96 to 156 in. Available stock thicknesses of ⅜, ⅝, ⅞, and 1⅛ in. include a finish allowance of 1/16 in. per side for oxide removal. Mechanical properties of plate material are as good as those of forgings. *Ampco Metal, Inc.*

For further information circle No. 555 on literature request card, p. 48B

Heat and Corrosion Resistant Materials

Corrosion-Resistant Valve



"Impervite" graphite is used as a protective lining in piston-type angle valves made by *Falls Industries, Inc.* This impervious lining is unaffected by all corrosives (except a few highly oxidizing agents) and will not crack or chip as a result of thermal shock. These free-flowing valves, with standard ASA flanges, cannot be overtightened because they do not utilize a seat. Impervite valves are furnished in 2, 3, 4, and 6 in. sizes for use at temperatures up to 340° F. and pressures to 150 psi.

For further information circle No. 556 on literature request card, p. 48B

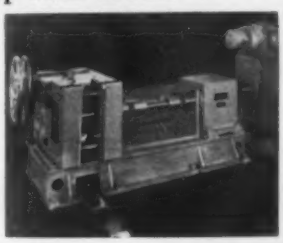
Cutting and Forming Equipment

Tensiometer for Cold-Rolling Mills

Continuous, direct measurement of strip tension on cold-rolling mills is possible with an indicating and regulating tensiometer made by *Allis-Chalmers Manufacturing Co.* The instrument can be applied to mills of any width, running at strip speeds up to 8000 fpm. Since maximum deformation of the tensiometer is only 0.002 in., springs and hydraulic cylinders used in other devices are eliminated. Mechanical accuracy is assured, maintenance is reduced, and no amplification of electrical output signal is required.

For further information circle No. 557

Mill Produces Nickel Strip From Powder



A metal purity of 99.9% and a density of 100% can be obtained in rolling nickel strip on the "Model 1000" horizontal compacting mill. In operation fine metal powder is continuously fed into the mill at a controlled rate. Green strip, leaving the mill at speeds up to 50 fpm., passes into a sintering furnace which has a protective atmosphere. The strip is then reduced on a two-high hot mill and a four-high cold mill of conventional design. *Loma Machine Mfg. Co.* states that the Model 1000 mill is also producing nuclear fuel elements, stainless steel filters, and copper radiator stock.

For further information circle No. 558 on literature request card, p. 48B

Industrial Heating Equipment

Vacuum Tempering Furnace

Ipsen Industries announces a 9-kw. vacuum tempering furnace with a maximum operating temperature of 1500° F. and a minimum operating pressure of 50 microns Hg. The unit also works with reducing, oxidizing, or inert gases under partial or full pressure. In addition to bright tempering, the "Series VVD" furnace – with a 10 in. diameter by 14 in. deep workspace – can be used for annealing ferrous and nonferrous metals, as well as precipitation hardening such alloys as 17-7 PH, 17-4 PH and beryllium copper.

For further information circle No. 559

Ceramic Muffle Tubes

The *McDanel Refractory Porcelain Co.* is producing gas-tight ceramic muffle tubes for high-temperature heat treating in vacuum or controlled atmospheres. Available in a wide range of sizes and lengths, the tubes provide dependable performance at temperatures to 3000° F.

Circle No. 560 on card

what goes up (impurities)
keeps your costs down...

what remains...

gives you new standards of trouble-free performance in specialty steel applications*

*Ask your Carpenter representative to prove how Carpenter's exclusive MEL-TROL® process can help you bring down costs, reduce rejects in your plant.

Carpenter steel

you can do it ***consistently*** better with Carpenter Specialty Steels for Specialists

The Carpenter Steel Company, Main Office and Mills, Reading, Pa.
Alloy Tube Division, Union, N. J.
Webb Wire Division, New Brunswick, N. J.
Carpenter Steel of New England, Inc., Bridgeport, Conn.

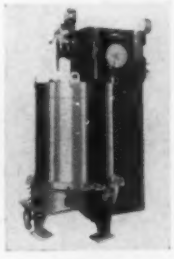
Circle 794 on Page 48-B

Direct Conversion to Infrared Heat

Gas energy is directly converted to flameless infrared heat energy on a catalytically active metal screen – resulting in increased efficiency and lower fuel costs. These completely controllable units produce temperatures between 800 and 1500° F. suitable for baking, drying, curing, bonding, preheating, softening, and evaporating. Standard sizes of catalytic panels provide heat release rates between 2000 and 12,000 Btu. per hr. per sq. ft. of emission surface (equal to 4 to 25 watts per sq. in.). *Catalytic Combustion Corp.*

For further information circle No. 561 on literature request card, p. 48B

Bright Tempering of Stainless Steel

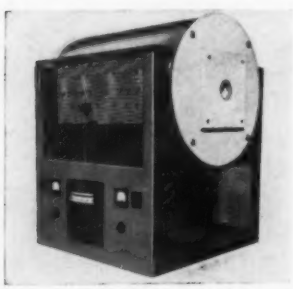


For heat-processing operations involving rapid cycling and precise control of temperature and protective atmosphere, *C. I. Hayes, Inc.* offers their "Bell-Temp" atmosphere furnace. High-velocity convection circulation of the atmosphere assures fast heat-up and uniform heat distribution. Atmosphere generators ("endo", "exo", nitrogen or ammonia dissociators) and instruments for precise temperature control (250 to 1250° F.) can be supplied for this tempering furnace.

For further information circle No. 562 on literature request card, p. 48B

Combustion Tube Furnace

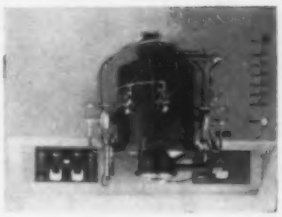
The "Model SC-32" furnace produces a uniform temperature of 2600° F. in a 12 in. long by 2½ in. O.D. ceramic tube. It is rated 7 kw. on 220/1/60 v.a.c. The "Thermionik" power control employs



thyratrons for greater accuracy of temperature control and lower initial cost. Heat dissipation to ambient has been reduced by use of high-temperature refractory insulation. *Despatch Oven Co.*

For further information circle No. 563 on literature request card, p. 48B

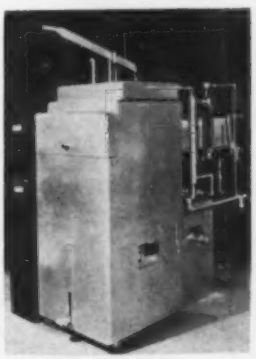
High-Temperature Vacuum Furnace



This carbon resistor furnace provides continuous service at 3000° C. (5430° F.) under vacuum, controlled reducing, or inert atmospheres. The split-graphite elements, which produce a 4 in. I.D. by 8 in. high hot zone, are designed for easy replacement (they may be fabricated from standard graphite pipe). Furnace sizes up to 30 in. can be custom built by *Vacuum Specialties Co., Inc.*

For further information circle No. 564 on literature request card, p. 48B

Electric Brazing Furnace



Companies doing their own heat treating will find this high-temperature electric furnace, incorporating a controlled atmosphere cooling chamber, to be very useful. It is ideally suited for brazing operations on small tools, dies, and production parts. A maximum temperature of 2400° F. permits heat treatment of all types of high-speed steels. The furnace, with a workspace of 8 by 6 by 14 in. long, has many

Save Time—Save Labor—Save Material

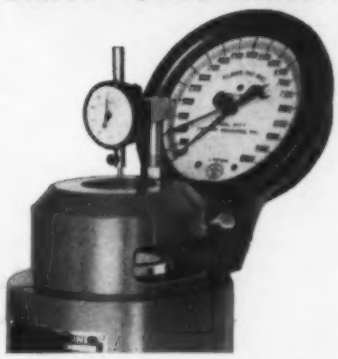
with Steel City Ductility Testers

Test incoming material for drawing qualities to be sure it will do the job for which you bought it and you'll avoid scrap and eliminate costly wasted effort. How? With a Steel City Ductility Testing Machine. Two concentric pistons do the job. Outer piston grips test piece against head; inner piston makes the cup. Gripping and load application are automatic. Piston speed is easily adjustable.

Distributors in most major metalworking areas

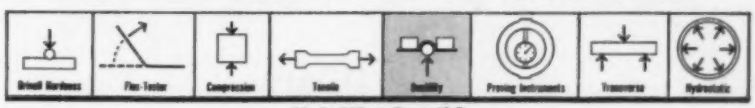
Steel City Testing Machines Inc

8811 Lyndon Ave., Detroit 38, Mich.



Available in two compact floor models for thicknesses up to ⅛" and ¼", and a bench model for thin metals 0.001" to 0.062". Hydraulic capacities up to 40,000 lb. Specimens up to 4" wide tested with ease. Depth indicator incorporates friction brake to hold readings. Easy-to-read load gage has maximum-indicating hand. Write for detailed specifications.

Write or call Steel City if you have any special testing problems



Circle 795 on Page 48-B

506

BOTH AVAILABLE ON CRONAR*

510

The superior dimensional stability of "Cronar" polyester film base—plus its unique strength and clarity—are now integral parts of Du Pont Type 506 and Type 510 Industrial X-ray Films.

You'll appreciate the critical definition and vivid images available on these fine Du Pont emulsions. You'll also have added precision with the size-holding ability of "Cronar", which approaches glass. A new optical clarity in your radiographs will make testing easier, more exact.

Processing will be faster, and drying easier too. The "Cronar" base lies flat, absorbs practically no moisture, stays taut in the hangers. "Cronar" is highly resistant to crimping, with minimal stretch or shrink with temperature and humidity changes. This means satisfactory results even under abnormal shop or field conditions.

Because you work to the very strictest specifications on fine tolerances with great responsibilities, you'll be certain to appreciate all of the qualities of Du Pont "Cronar" 506 and 510 Industrial X-ray Films. And they are only two of the many radiographic films developed by Du Pont.

For more information on these and other equally fine industrial x-ray products, write us at E. I. du Pont de Nemours & Co. (Inc.), Photo Products Department, Wilmington 98, Delaware. In Canada: Du Pont of Canada, Ltd., Toronto.

*Du Pont's registered trademark for its polyester photographic film base

DU PONT
REG. U.S. PAT. OFF.

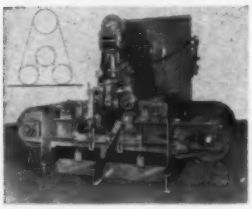
BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

applications in foundry metalworking and manufacturing operations, as part of a production line or handling special jobs in a small shop. *Waltz Furnace Co.*

For further information circle No. 565 on literature request card, p. 48B

Cleaning and Finishing

Dual-Contact Sheet Polisher



An endless abrasive belt, which contacts the work twice in one pass, provides double the surface finishing ability of standard, single-contact flat polishing machines. Abrasive belts up to 60 in. wide may be operated dry or with a mist spray or grease to produce decorative finishes. The oil-resistant neoprene conveyer belt can be driven at speeds varying from 20 fpm. to 60 fpm. *Murray-Way Corp.*

For further information circle No. 566 on literature request card, p. 48B

Deburring Machine

A variety of metal parts can be rapidly processed in the "Model DB1616 Space Saver", which features a two-compartment barrel with a total capacity of 2 cu.ft. A single compartment barrel, measuring 16 in. in length and diameter, permits operating flexibility. The barrel – lined with abrasive-resistant plastisol – can be rotated at speeds varying from 13 to 39 rpm. *King-Seeley Corp.*

For further information circle No. 567 on literature request card, p. 48B

Airless Spray Gun

The spray gun itself has always been the limiting factor in airless spray efficiency. The "Versa-Gun" features an internal design that increases turbulence ahead of the nozzle, thus providing atomization at lower pressure. The controlled spray pattern produces correctly feathered edges for proper overlap of gun passes. The Versa-Gun may be used with heated or unheated airless systems, and is available in circulating or "dead-end" models. *Nordson Corp.*

For further information circle No. 568 on literature request card, p. 48B

Alkaline Rust Remover

Turco Products, Inc. announces a nonflammable product for removing scale, carbon, and paint from ferrous metals without the danger of hydrogen embrittlement or loss of dimensional tolerances. "Alkaline Rust Remover" – which contains no cyanide compounds and emits no corrosive fumes – is utilized in a one-tank operation followed by a pressure rinse. Because of its characteristics, this rust remover minimizes re-rusting of metal after processing; no after-neutralization is required.

For further information circle No. 569 on literature request card, p. 48B

Welding and Joining

Ultrasonic Foil Welder

A 10-watt "Glennite" ultrasonic welder can spot-weld foil in thicknesses ranging from 0.00025 to 0.0002 in. The welds are as strong as the parent metal. Applications for the welder include joining gold, silver, and aluminum leads to semiconductors and producing hermetic seals in a variety of materials. A micro-second timer and binocular microscope are available for precision welding applications. *Gulton Industries, Inc.*

For further information circle No. 570 on literature request card, p. 48B

NEW KENTRALL HARDNESS TESTERS are Motorized

By removing major test loads automatically, the new motorized Kentralls reduce operator error, increase reproducibility of test results, and raise the productive capacity of the machine—for the same price as hand operated testers.

The motorized Kentralls are available in Combination Testers which provide both Regular and Superficial Rockwell Hardness Testing in a single machine. For those applications that do not require the additional range, Kentrall also makes single purpose testers for either Regular or Superficial testing alone.

For complete information write for Bulletin CRS 60

KENTRALL THE TORSION BALANCE COMPANY
Main Office and Factory: Clifton, New Jersey
Sales Offices: Chicago, San Francisco

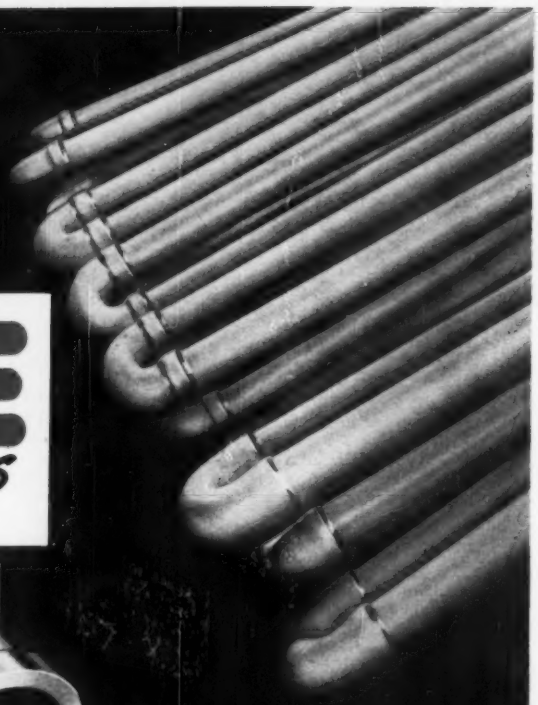
TB163

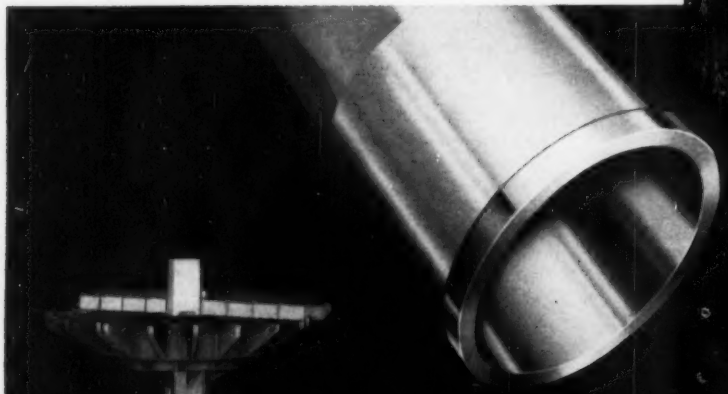
Circle 797 on Page 48-E

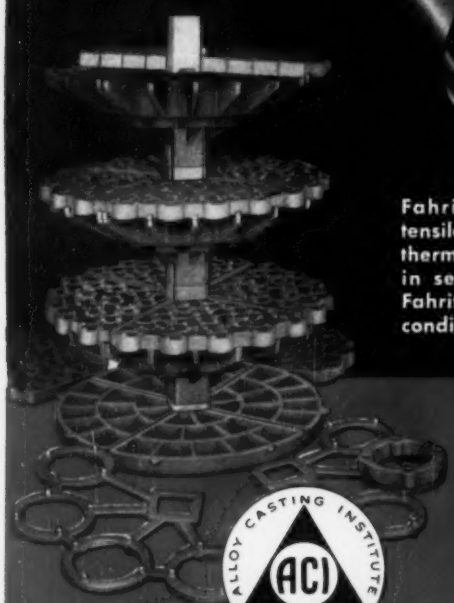
CASTINGS FOR HIGH TEMPERATURE SERVICE

FAHRITE

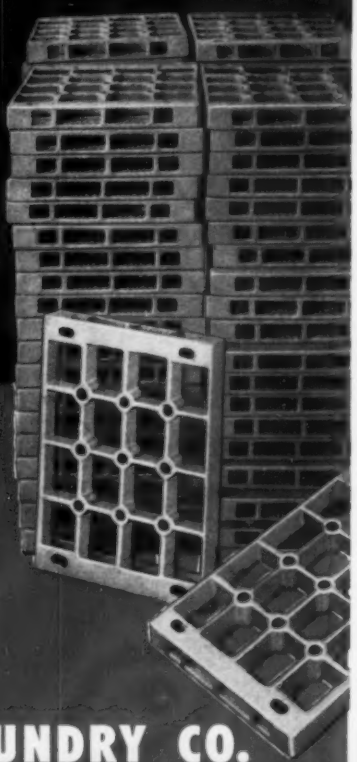
HEAT AND CORROSION *Alloys*







Fahrite alloy castings have high tensile strength, high resistance to thermal shock and stand up longer in service. There are grades of Fahrite to meet your exact operating conditions.



It will assist OHIO engineers in preparing quotations for you to furnish complete operating conditions.

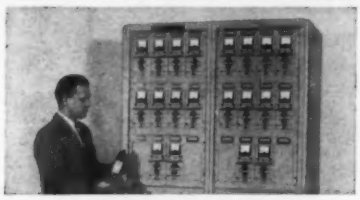
ALLOY CASTING INSTITUTE ACI MEMBER

THE OHIO STEEL FOUNDRY CO.

SPRINGFIELD, OHIO

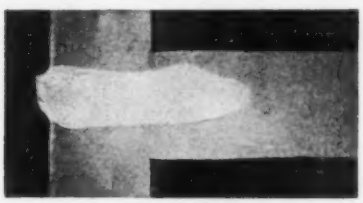
Plants at Springfield and Lima, Ohio

NEWS from the NRC Vacuum MICRONICLE*



ALPHATRON® GAUGES SPEED ANALYSIS OF HYPERSONIC DATA

The tried and true Alphatron® ionization vacuum gauge now has a new job — speeding the results of hypersonic wind tunnel tests. Multi-point pressures are measured almost instantaneously and fed into high speed computers. Accuracy is better than ±2% in the range of 1-30 mm. Hg. The 20 channel system pictured above is a modification of the standard Alphatron® gauge, which provides continuous and accurate measurements of pressure from 1000-0.0001 mm. Hg.



ELECTRONS WELD THE UNWELDABLE!

Welding problems posed by reactive metals, dissimilar materials, heat sensitivity, or unusual geometry are now solved with electron beam welders. Freedom from contamination, porosity, and distortion; spot size controllable from 10 mils to 3 inches; depth/width ratios of 4/1; and precision welding at the bottom of 1/16 inch wide slot are some of the advantages of the new process. And equipment prices are surprisingly low.

***Free NRC Vacuum Micronicle**

a periodical containing details of above and other news about making products better with NRC high vacuum equipment. Write on your company letterhead.

NRC EQUIPMENT CORPORATION

A Subsidiary of National Research Corporation

Dept. M-2, 160 Charlemont St., Newton 61, Mass.
DEcatur 2-5800

NEO-13

Hardsurfacing Process

The "Aircospray" hardfacing process simultaneously sprays and fuses powdered metals on the base metal by means of an oxyacetylene flame. The Aircospray equipment includes a powder dispenser, a carrier gas source (argon, helium, nitrogen, or CO_2) and a modified torch tip on

a standard oxyacetylene outfit. The method works equally well on thin or thick base-metal sections and can deposit a uniform, smooth surface as thin as 0.003 in. When used with silver filler alloys, the Aircospray method provides true capillary brazing with deep penetration.

For further information circle No. 571 on literature request card, p. 48B

Jet Spray Gun

A new housing and heat shield on the "SG-1 Plasmatron" gun reduces operator fatigue and increases efficiency in depositing coatings of refractory materials such as tungsten for rocket nozzle linings. Other uses include "re-entry" testing of

nose-cone materials, cutting refractory metals, and synthesizing organic chemicals. The Plasmatron features a capacitance-type, low-voltage arc starting device, a plasma-jet temperature control, and water cooled electrodes for long life. *Plasmadyne Corporation.*

For further information circle No. 572 on literature request card, p. 48B

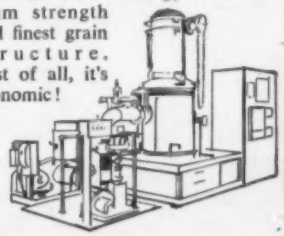
Spotwelder For Small Parts

The "Model 369B" bench welder can be used to join small components — made of nickel, tantalum, molybdenum, kovar and other alloys — into electronic and miniature devices. Standard equipment includes

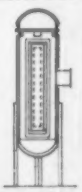
HERBERT W. WESTEREN, Assistant Director of Hayes Research and Development Group, tells about the . . .

"VACUUM AGE" OF HEAT TREATING

A major New York manufacturer of aircraft equipment recently reported their Hayes Vacu-Master Cold Wall Furnace was paying off in many ways — providing rapid cycling, simplified work handling, and complete production flexibility. Additionally, the vacuum furnace has eliminated need for atmosphere equipment . . . and produced work (stainless steel brazing) of maximum strength and finest grain structure. Best of all, it's economic!

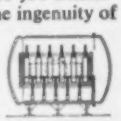


Similar Success Stories come to us from other users of Hayes Furnaces. Successful heat treating of "exotic" metals (tantalum, titanium, niobium, etc.) in the 2600 to 4500°F range. Successful sintering, hardening, annealing, and degassing at high production rates. Success stories all around!



The "Universal Atmosphere" has Universal Applications

Unlike other "atmospheres," vacuum has virtually no job limitations. Here's where the ingenuity of Hayes development engineers comes into play. By coordinating furnace design with job requirements . . . and by PROVING RESULTS in the Hayes lab . . . Hayes vacuum furnace engineers assure the customer a "RESULTS GUARANTEED" installation every time. I'd like to invite you to advance your heating into the "vacuum age" . . . with HAYES!



Write for vacuum Bulletin 5709A.

C. I. HAYES, INC.

Established 1905

802 WELLINGTON AVE. • CRANSTON 10, R. I.

It pays to see Hayes for metallurgical guidance, lab. facilities, furnaces, atmosphere generators, gas and liquid dryers, Pow-R-Trol (TM) control units.

Circle 799 on Page 48-B

why new/improved Hotform

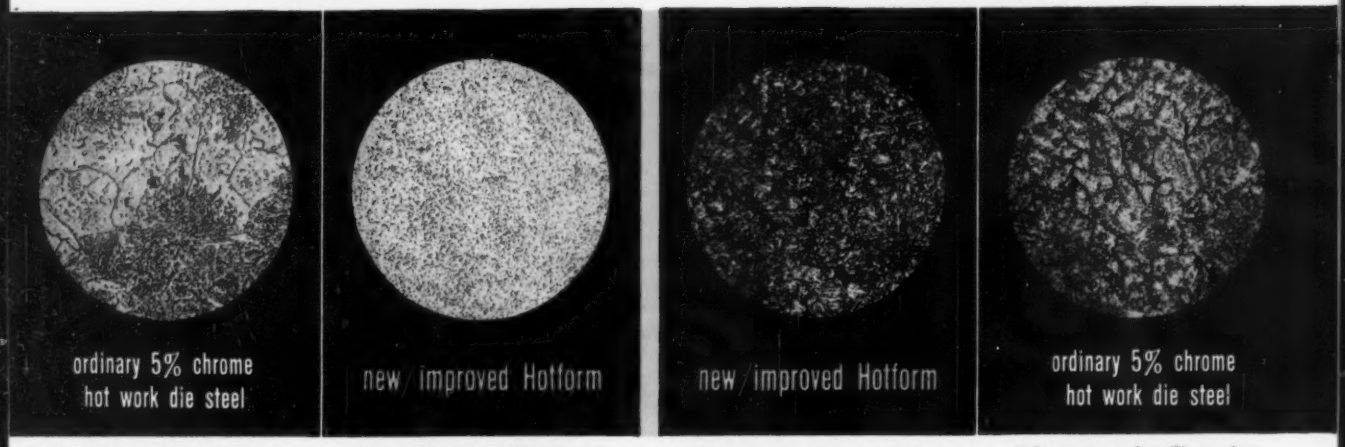
U. S. Pat. 2,883,902 July 7, 1959

offers unparalleled increases in die life and service—

corrects heat checking and cracking

study the story these photomicrographs tell:

ANNEALED | **HEAT-TREATED ROCKWELL "C" 50**



Structure is typical of large sections of H-11, H-12 and H-13 type steels commonly on the market. Note carbide segregate and envelopes in grain boundaries. This structure persists through heat treatment to form lines of discontinuity that initiate cracks.

Note uniform distribution of pinpoint carbides—freedom from carbide segregate in grain boundaries —freedom from carbide stringers. This structure, guaranteed in New/Improved Hotform, increases toughness and ductility of heat treated dies up to 35%.

Structure of New/Improved Hotform after heat treating to Rockwell "C" 50. Note uniformity of structure that improves ductility.

Note coarse grain with envelope structure. Die failures due to gross cracking invariably possess this structure or worse.

New/Improved HOTFORM's fine, uniform structure is the culmination of an intensive research and development program to assure longer die life in service. Now, greatly increased resistance to pitting, impingement soldering and heat checking make New/Improved HOTFORM more than ever your first choice for first quality hot work dies. Let us detail the vital facts for you!

TENSILE PROPERTIES

0.505 specimens, 3 tests per condition, heat treated simultaneously

Manufacture	Size	Location of Test	Hardness Rc	Tensile Strength psi	Ductility (Red. of Area %)	% Improvement
Standard	15½" sq.	Midradius Transverse	49.6	250,000	12.9	28
Improved	15½" sq.	Midradius Transverse	49.6	256,000	16.5	
Standard	8" sq.	Center Transverse	50.3	255,000	10.7	38
Improved	8" sq.	Center Transverse	51.4	265,000	14.8	

IMPACT PROPERTIES

Charpy V-notch specimens, 6 tests per condition, heat treated simultaneously

Manufacture	Size	Location of Test	Hardness Rc	Average Impact Strength ft.-lbs.	Statistical Scatter	% Improvement
Standard	15½" sq.	Midradius Transverse	51.6	10.8	±2.9	20
Improved	15½" sq.	Midradius Transverse	51.6	13.0	±1.8	

VANADIUM-ALLOYS STEEL COMPANY

LATROBE, PENNSYLVANIA

DIVISIONS: Anchor Drawn Steel Co. • Colonial Steel Co. • Metal Forming Corporation • Pittsburgh Tool Steel Wire Co.

SUBSIDIARIES: Vanadium-Alloys Steel Canada Limited • Vanadium-Alloys Steel Societa Italiana Per Azioni • EUROPEAN ASSOCIATES: Societe Commentryenne Des Aciers Fins Vanadium-Alloys (France) • Nazionale Cogne Societa Italiana (Italy)

Circle 800 on Page 48-B

a diaphragm head, electrical and pneumatic controls, and welding transformer from 300 to 2000 va. Both the standard a-c. control and a new "Pulse-Firing Power System" allow a wide range of materials (and thicknesses) to be welded. The latter control transmits extremely high energy to the work in about a millisecond, for a more efficient welding operation with little heat dissipation. *Sciaky Bros., Inc.*

For further information circle No. 573 on literature request card, p. 48B

Plasma Cutting Torch

With plasma velocities over 10,000 mph. and temperatures of 50,000° F., the "Plasma Flame Torch" develops spectacular cutting speeds – 200 ipm. for ½ in. stainless or aluminum plate. It will also cut copper, tungsten, and molybdenum. Simple controls for gas mixtures (nitrogen, argon, hydrogen), gas velocity, and electric power permit quick adjustment for metal thickness and cutting speed. The high velocity of the plasma produces smooth cuts. *Thermal-Dynamics Corp.*

For further information circle No. 574

Three-Phase AC-DC Welder

The "Controlarc Model 330", with three-phase input, has a range of 6 to 400 amp., d-c., and 6 to 250 amp., a-c. Continuous, dual control is maintained on both a-c. and d-c. with adjustable arc characteristics (curve slope and response speed). The unit provides special low-range a-c. for high-performance, low-current TIG and stick-electrode welding, plus remote control units for adjusting a-c. or d-c. output current. *Vickers Inc*

For further information circle No. 575 on literature request card, p. 48B

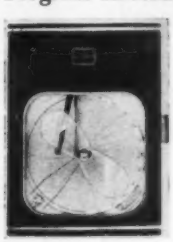
Inspection and Control Equipment

Heavy-Duty X-Ray Machine

A 150 kv. X-ray unit produces sharper pictures due to the tube's 0.012-in. (0.3-mm.) focal spot – the smallest available. The rotating, water-cooled anode tube has a continuous rating of 6 milli-amp. at 150 kv., twice the output of a stationary tube. The counterweighted three-inch-square mast eliminates vibration, and can be pivoted through 360°. The machine is especially suited for applications requiring large amounts of nondestructive inspection. *Picker X-Ray Corp.*

For further information circle No. 576 on literature request card, p. 48B

Program Recorder-Controller



The recorder chart and the program cam are independently driven in the "Series 500" single-case instrument. This makes it possible to record repetitions of the program – which may last from 30 min. to 30 days – on a single chart. Various models of the unit measure and control temperature, pressure, flow, liquid level, and humidity. Either pneumatic control or "Free-Vane" electronic control is available. Pneumatic operation can be either "on-off", proportional, or reset control. *Bristol Co.*

Circle No. 577 on literature request card, p. 48B

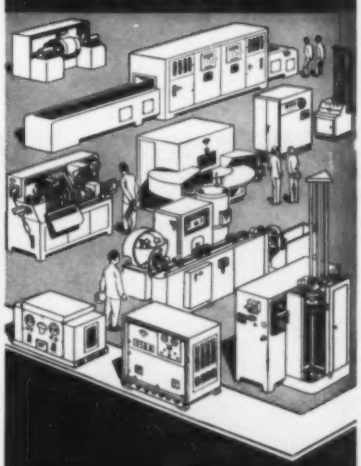
Production and Casting Equipment

Refractory Gun

A wet-mix refractory gun, "Model W-K", makes possible easier, faster repairs to hot openhearth and electric furnaces. The 1-in. gun will propel refractory material up to No. 4 mesh in size mixed with accurately proportioned water additions ranging from 15% upward, depending on furnace temperature. The 1900-lb. capacity unit is operated by a two-man team; rates of delivery can be varied up to 500 lb. per min. *Basic Incorporated.*

For further information circle No. 578 on literature request card, p. 48B

for HARDENING • BRAZING
SOLDERING • FORGING • ANNEALING
MELTING • SINTERING • WELDING
REFINING • SHRINK FITTING
CRYSTAL GROWING



THER-MONIC

Manufactures the most complete range of

INDUCTION HEATING EQUIPMENT

ELECTRONIC • LOW FREQUENCY
MOTOR GENERATOR

THER-MONIC features

• Over 20 years of concentrated experience.

• Over 5,000 installations.

• Over 15,000 heating applications resolved in our customer service laboratories.

• This outstanding experience and know-how qualify us to prescribe the techniques and equipment best suited for your requirement.

Contact our factory or your local IHC representative.

Write for New 56-page catalog of exclusive features, facts and specs.

INDUCTION HEATING CORP.
181 WYTHE AVE., BROOKLYN 11, N.Y.

Subsidiary of Hathaway Instruments, Inc.

Circle 801 on Page 48-S

Whether you choose by specification, price or both . . .

There's a Honeywell to fit your

As low as $50.00

☐ **For precise control at low cost—R7086—R7087**

Temperature controllers for use wherever precision temperature control must be maintained. Ranges from −150° to +3000° F. are possible. (R7086 uses thermo-couple, R7087 use resistance bulb.)

R7087, $120.00

$84.00

☐ **For accurate control with indication, at low cost**

T654A indicates and controls temperatures on an evenly graduated scale accurate within 1% of scale range. This switch can control an *Actionator**, motor, relay, contactor or other device. Completely compensates for ambient temperature changes.

temperature or pressure control exact needs!

As low as $49.50

☐ **For reliable control at minimum cost VERSA-TRAN**

This inexpensive controller is completely transistorized. Needs no tubes, no warm-ups . . . gives instant reaction. Works with sensors that can be thermisters, probes, resistance bulbs, pressure transducers or humidity elements. Available in various temperature, humidity and pressure ranges.

Standard models as low as $39.50

Check these other models in the complete Honeywell line of temperature and pressure controls

P444
For industrial applications that call for independent high-pressure and low-pressure settings and switching action. Adaptable for surface or flush mounting.

T444
For a wide variety of industrial applications that require independent high-temperature and low-temperature settings and switching action.

P428
For general industrial applications requiring the control or limiting of relatively high pressures. Models are made with explosion-proof case for installation in hazardous locations.

T667
Designed for use as a remote-bulb temperature controller. SPDT switching provides temperature control in heating, cooling, or heating-cooling commercial and/or industrial applications.

Honeywell

First in Control

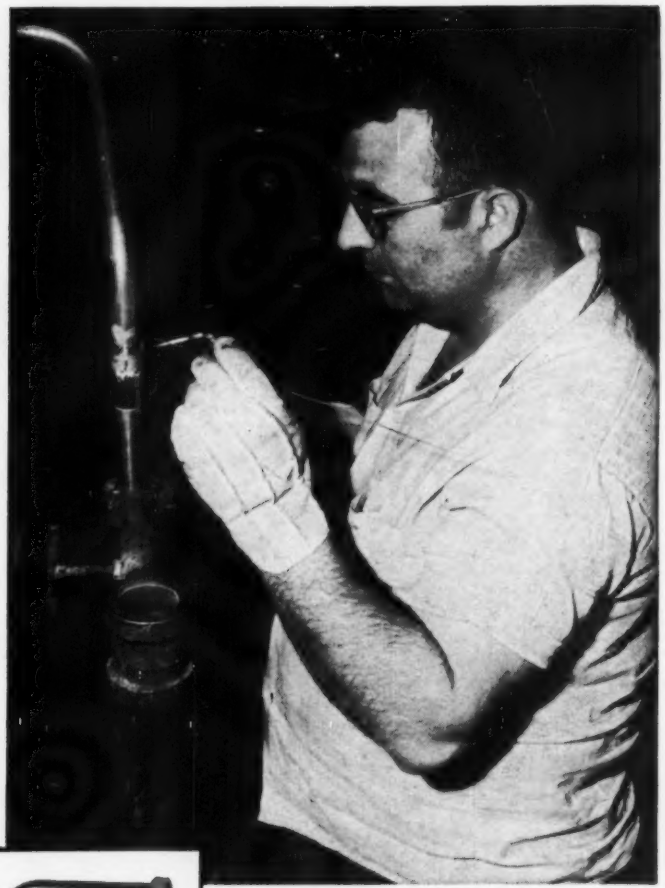
SINCE 1885

*Trademark

Circle 802 on Page 45-B

Titeflex, Inc., Meets Aircraft Fuel, Lubrication and Hydraulic Line Specifications with

HANDY & HARMAN BRAZE 541



Titeflex operator brazes assembly with torch and hand-fed Handy & Harman Alloy BRAZE 541. *Titeflex is unique in that it makes flexible hose assemblies from raw material to end product—"From End to End, Inside and Out, made RIGHT In Our Own Plant."*

This Springfield, Massachusetts, manufacturer of aircraft and missile fuel, lubrication and hydraulic lines finds that silver alloy brazing with Handy & Harman BRAZE 541 meets rigid operating requirements "all the way down the line."

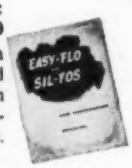
The tubing and fittings of many of the wide range of assemblies made by Titeflex are 321, 316 and 347 stainless steel and Monel. Brazing is a hand torch, wire and HANDY FLUX operation.

BRAZE 541 is a plastic alloy which melts at 1325° F and flows at 1575° F. Its strength—in shear—at elevated temperatures is 21,500 psi at 500° F and 15,000 psi at 750° F. This alloy's ductility in resisting stress and vibration is very high and its resistance to oxidation and corrosion is equally impressive. The composition of BRAZE 541 is 54% silver, 40% copper, 5% zinc and 1% nickel. It meets AMS Specification 4772.

Aircraft and missile component manufacturers and fabricators are finding—to their and their products' benefit—that Handy & Harman silver alloy brazing is the full and *final* solution to their metal-joining problems. BRAZE 541 is but one of a large family of Handy & Harman alloys, for both low and high temperature applications. We would like to more fully acquaint you with BRAZE 541 and with the advantages that come naturally to silver brazing as a metal-joining (both ferrous and nonferrous) method. Handy & Harman, 82 Fulton Street, New York 38, N. Y.

FOR A GOOD START: BULLETIN 20

This informative booklet gives a good picture of silver brazing and its benefits . . . includes details on alloys, heating methods, joint design and production techniques. Write for your copy.



Your No. 1 Source of Supply and Authority on Brazing Alloys

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General Offices: 82 Fulton St., New York 38, N. Y.

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Los Angeles, Calif.
San Francisco, Calif.
Toronto, Canada
Montreal, Canada

Circle 803 on Page 48-B

Consider the long range payout of Titanium vs standard metals and alloys

Wolverine Tube is certain that you know all about equipment payout—and how it can be affected by costly maintenance and downtime, particularly in corrosive services.

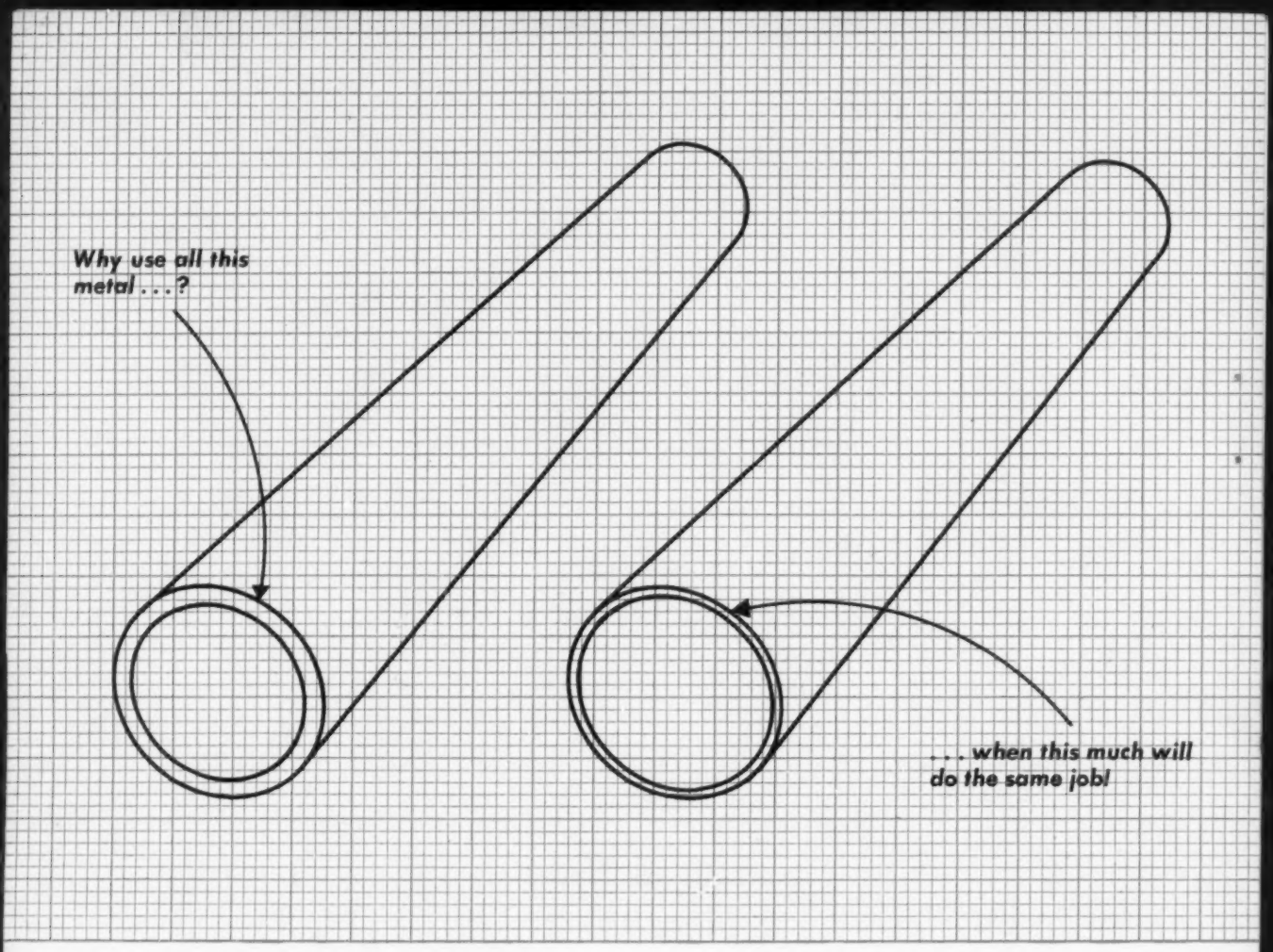
But perhaps you haven't considered how important it is to look beyond first costs—to get the big picture of what Wolverine titanium heat exchanger tubing can do for your company's long range requirements.

In addition to the services illustrated in the charts above, consider the increasing use of sea water for cooling purposes. Most ferrous and nonferrous alloys in this service have a tendency toward stress corrosion cracking and pitting. On the other hand, titanium is completely immune to these faults when handling salt water. Thus, as in the services charted above, titanium heat exchanger tube, though having a greater first cost, is more economical in the long run because it gives greatly increased and uninterrupted service life.

It's a big subject and one that requires more space than we have available here. Why not talk it over with your Wolverine sales representative? He can point out in detail the many ways in which titanium heat exchanger tube can save you time and money.

WOLVERINE TUBE
DIVISION OF
Calumet & Hecla, Inc.
DEPT. J, 17252 SOUTHFIELD RD., ALLEN PARK, MICH.
Manufacturers of Quality-Controlled Tubing

PLANTS IN DETROIT, MICHIGAN AND DECATUR, ALABAMA. SALES OFFICES IN PRINCIPAL CITIES.



Wolverine Titanium Heat Exchanger Tube helps eliminate waste metal

When analyzing the effectiveness of titanium heat exchanger tubing, in comparison with standard metals and alloys, it must be remembered that because of titanium's great resistance to corrosion, a lighter walled tube can be used in many applications.

For example, Wolverine titanium heat exchanger tube with .049" wall thickness and less can successfully handle products such as acetic acid, nitric acid and chlorine—among others. When compared to the much heavier walled tubing in certain other metals normally used in such services, it is apparent that substantial savings can be made in both unit weight and structural support.

This important factor also helps reduce the end cost of titanium heat exchanger tube and makes this metal even more attractive when compared to other metals having lower initial cost, but requiring heavier wall thickness because of their accelerated corrosion rate.

For complete information about Wolverine titanium heat exchanger tube, just talk to your Wolverine sales representative. He can give you the entire story about Wolverine's work in titanium and other special metals.

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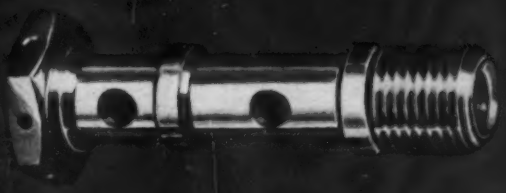
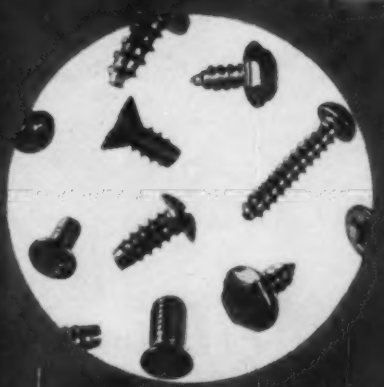
PLANTS IN DETROIT, MICHIGAN AND DECATUR, ALABAMA. SALES OFFICES IN PRINCIPAL CITIES.

you can drill it...



you can machine it...

you can head it...



but you can never, no never, change its consistent uniformity!

...your first order will convince you—Carpenter Specialty Stainless is easier to fabricate. Made by one of the leading producers of stainless steels for industry, Carpenter Specialty Stainless assures greater output, fewer rejects and increased profits.

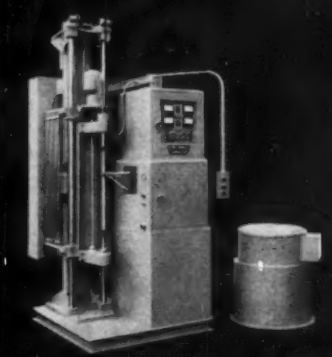
Carpenter steel

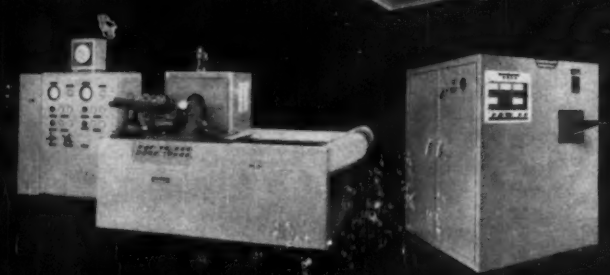
you can do it ***consistently*** better with Carpenter Stainless Steels for specialists

Circle 804 on Page 48-S

The Carpenter Steel Company, Main Office and Mills, Reading, Pa.
Alloy Tube Division, Union, N. J.
Webb Wire Division, New Brunswick, N. J.
Carpenter Steel of New England, Inc., Bridgeport, Conn.

Behind these doors heat is trained to serve the world of industry





Cincinnati heat engineers can analyze your particular heating problem, develop the necessary process, adapt a standard machine to the job, or design a special work-processing unit.

CINCINNATI®

center of thermotic science and research— creates ultra-modern machines for today's heat processing requirements

From ancient days, man has regarded the element of fire with great respect. Today, *Cincinnati Advanced Heat Engineering* has fashioned the heat of flame and electricity into remarkable tools of production.

From the knowledge gained by research and experience in heat engineering, Cincinnati has developed a complete line of ultra-modern heating equipment: Flamatic® flame heating and Inductron® radio frequency and motor-generator induction heating machines. Backed by extensive facilities, Cincinnati is recognized as a leading engineering source for the application of heat as a processing tool.

Cincinnati is ready to serve you with engineering calculations and the selection and tooling of heating equipment to solve many heat processing problems. As builders of both flame and induction heating machines, Cincinnati can give you truly unbiased recommendations for the most efficient and economical heat processing method. Whether your application is simple or complex, let the benefits of *Cincinnati Advanced Heat Engineering* work for you.

inductron
flamatic
heating machines
META-DYNAMICS DIVISION
Metal Forming and Heating Machines
THE CINCINNATI MILLING MACHINE CO.
Cincinnati 9, Ohio, U.S.A.
CINCINNATI

Circle 805 on Page 48-B

NEW LITERATURE

NEW LITERATURE • NEW LITERATURE • NEW LITERATURE •

Cast HT high-nickel alloy conveyor belt still going strong after 8 yrs. service at 1550°F

Resistance to sigma phase embrittlement and thermal fatigue . . . high temperature strength and castability make Type HT* alloy an ideal choice for conveyor belts, baskets, trays and other load-bearing furnace parts.

At one automotive plant, huge 105-ft. conveyor belts—cast of HT high nickel alloy—carry tractor links through continuous, gas-fired hardening furnaces like the one shown above.

And after eight years' service, carrying 3,000 lb. per hour through the 1550°F furnace atmosphere, these conveyor belts are still in operation and expected to give many more years of trouble-free service.

Engineers specified Type HT high-nickel alloy for these parts—for the rollers and idler drums used to rotate them, too—because of this alloy's complete freedom from sigma phase embrittlement, its strength and ductility. These properties, combined with this alloy's casting ease and economy, make it an ideal choice for conveyor belts, baskets, trays and other load-bearing members used in heat treating furnaces.

Wide range of alloys. Type HT alloy is just one of a family of high-nickel alloys available for heat-treating applications. In this family of alloys you'll find metals that provide good strength and long life at temperatures from 1200 to 2300°F. You'll find alloys with remarkable combinations of properties—properties needed to withstand oxidizing and reducing environments, carburizing and nitriding atmospheres.

If you have a high-temperature problem, there's a good chance you can solve it with the help of the 72-page booklet, "Heat Resistant Castings, Corrosion Resistant Castings . . . Their Engineering Properties and Applications." Write Inco for your copy today. Just ask for A-266. *A.C.I. designation

The International Nickel Company, Inc.
67 Wall Street INCO New York 5, N. Y.

INCO NICKEL

NICKEL MAKES CASTINGS PERFORM BETTER LONGER

Circle 806 on Page 48-B

Heat and Corrosion Resistant Materials

610. Refractory Grains
Catalog from *Norton Co.* describes a wide range of refractory materials. Physical, chemical, and electrical properties of Al_2O_3, MgO, boron carbide, and fused zirconia.

611. Graphite Cloth
Bulletin 101 presents detailed property data on graphite woven fabrics and their applicability to a variety of industrial uses. Textile characteristics are also included. *National Carbon Co.*

612. "Powder Metallurgy"
Quarterly publication of the *Metal Powder Industries Federation* (springsumer 1960) features case histories of electrical applications for powder metallurgy parts.

613. Heat-Resistant Castings
Electro-Alloys Div. will send information on "Supertherm," a heat-resistant alloy for castings operating in the 1800 to 2300° F. range.

614. Rene 41 Rings
Cannon-Muskegon Corp. has information on René 41 seamless rings forged from cylindrical castings. Other difficult-to-forge iron, nickel and cobalt alloys also produced.

615. Honeycomb Structures
8-p. pamphlet from *Hexcel Products, Inc.* tells about "Hexcel Honeycomb," a new structural material with an excellent strength-to-weight ratio.

616. Superalloy Forgings
Brochure on superalloy forgings—Waspaloy, René 41, Astroloy, Udimet 500, and M-252. *Wyman-Gordon Co.*

617. High-Alloy Castings
Bulletin No. 3150G from the *Duraloy Co.* discusses "Duraloy" castings for high-temperature applications.

618. Iron Powder
Pamphlet from *Alan Wood Steel Co.* presents data on iron powder, high in purity and uniform in size and composition.

619. Metal Powders
4-p. pamphlet lists uses for elemental pre-alloyed metal powders, including stainless steel, copper, aluminum and cobalt-base alloys. *Federal-Mogul Div.*

620. Corrosion Calculator
Chart calculator serves as a general guide in determining the serviceability of glass-lined products in a wide variety of chemicals. *A. O. Smith Corp.*

621. Glass-Coated Steel
20-p. booklet details the manufacturing steps, physical and chemical properties, and end use of "Glasteel." *Pfaudler Co.*

622. Tungsten Carbide
Pamphlet from *Clemet Products* on "Clec-ite," a granular tungsten carbide in five ranges of uniform grain size.

623. Molybdenum Products
Sylvania Electric Products will send information on refractory metal products made from controlled particle size powders.

624. Silicon Carbide
Pamphlet from *Norton Co.* describes "Crystolon 63," a low-cost nitride-bonded silicon carbide for refractory applications.

Tool Materials

625. Toolsteel Guide
A "Steelector" booklet from *Allegheny Ludlum* gives complete data on line of toolsteels . . . mechanical property and heat treating information included.

626. Chemical Milling
Eastman Kodak Co. has a brochure which presents information on "Metal-Etch Resist." It speeds up and simplifies chemical milling operations.

627. "Moly" Lubricant
The *Alpha-Molykote Corp.* will send a free sample of "Molykote G" lubricant plus their Bulletin 126 describing the product.

628. Molybdenum Disulphide
24-p. Bulletin 124 discusses the theory and practice of lubrication by solids, including advantages of using molybdenum disulphide solid lubricants. *Alpha-Molykote Corp.*

629. Toolsteel Heat Treatment
Bethlehem Steel Co. has complete details on short cycle hardening and nitriding of high-carbon, high-chromium toolsteels.

630. Closed Die Forgings
Brochure "The Automatic Production of Forgings in Closed Dies" contains examples of successful mechanized forging operations. *Chambersburg Engineering Company.*

631. Wire Straightener
"Shuster" wire straightening and cutting machine improves your product while it cuts your costs. Details from *Mettler Machine Tool, Inc.*

632. Die Steel
Characteristics and typical applications of "C Annealed" (6H55) die steel are contained in Data Sheet No. 8 published by *Heppenstall Co.*

633. Hole-Punching Equipment
10-p. brochure presents production economies of "Unipunch Unitized Tooling" in applications involving presses and press brakes. *Punch Products Corp.*

634. Diamond Abrasive
Bulletin No. 7 reviews latest advances in the uses of diamond abrasives. Comparisons are made between man-made and selected natural diamonds. *Diamond Tool Research Co., Inc.*

635. Strip Shears
4-p. pamphlet on air and hydraulically operated shears for strip and bar stock has been published by *Curry Air Shear Corporation.*

636. High-Speed Steels
Data sheets from *Vanadium-Alloys Steel Co.* discuss applications—abrasion, impact, high temperature—for various grades of high-speed steel.

637. Tube Mills
For complete information on pipe or tube mills, write for illustrated 88-p. tube mill book. *Yoder Co.*

638. Colloidal Graphite
Interested in lubrication efficiency for metalworking operations? Send for bulletin 426 from *Acheson Colloids Co.*

639. Metallic-Base Lubricant
Bulletin 46 describes "Fleximet PCM," a heat stable protective lubricant fortified with extreme pressure additives. *Swift & Company.*

640. Die Blocks
Bulletin 200 tells how to care for and get more production out of die blocks from *A. Finkl & Sons Co.*

641. Toolsteel Comparison
Bethlehem Steel Co. has published a 16-p. booklet comparing the properties of four outstanding tool steels—A-4, D-2, A-2, and O-1.

642. Anti-Scoring Lubricant
4-p. brochure discusses "CMD" extreme pressure anti-scoring lubricant for machine tool and other manufacturing processes. *Chicago Manufacturing & Distributing Co.*

Industrial Heating Equipment

643. Thermostatic Bimetals
Pamphlet reviews applications for 36 types of thermostatic bimetals—in coils, strips and completely fabricated elements. *W. M. Chace Co.*

644. Thermal Fatigue
Electro-Alloys Div. has published "The Mechanism of Thermal Fatigue" by H. S. Avery.

645. Wall Chart
The *Claude S. Gordon Co.* will send Tempil's "Basic Guide to Ferrous Metallurgy," a plastic laminated wall chart in color.

646. Fluidized Bed Heat Treating
4-p. Bulletin GED-4306 describes fluidized bed heat treating equipment for annealing, normalizing, solutioning, aging, hardening, quenching and isothermal transforming. Up to 85% reduction in heating time. *General Electric Co.*

647. Induction Heating
The *Ohio Crankshaft Co.* will send brochure "Typical Results of Tocco Induction Heating—Principles, Applications, Equipment."

648. Heat Treating Small Tools
Get the story from *Waltz Furnace Co.* on a complete setup for heat treating small tools—contains a pre-heat furnace, a high-heat furnace and quench tanks.

649. Thermocouple Assemblies
Catalog G100-1 gives the details on 100 complete thermocouple assemblies, a range wide enough to cover most applications in industry. *Minneapolis-Honeywell.*

650. Radiant Tubes
Catalog from *Pressed Steel Co.* discusses line of radiant tubes in any alloy, size or type.

651. Temperature Control
Leaflet from *Alnor Instrument Co.* sets forth details on "Pyrotroller" a dependable automatic temperature control for heat processing.

652. Induction Furnaces
Bulletin 70 from *Inductotherm Corp.* illustrates line of induction furnaces with capacities up to 100 kw.

653. Car-Bottom Furnace
Bulletin 644R describes car bottom furnace for heat treating castings up to 54 in. in diameter and 30 ft. in length. *Hevi-Duty Electric Co.*

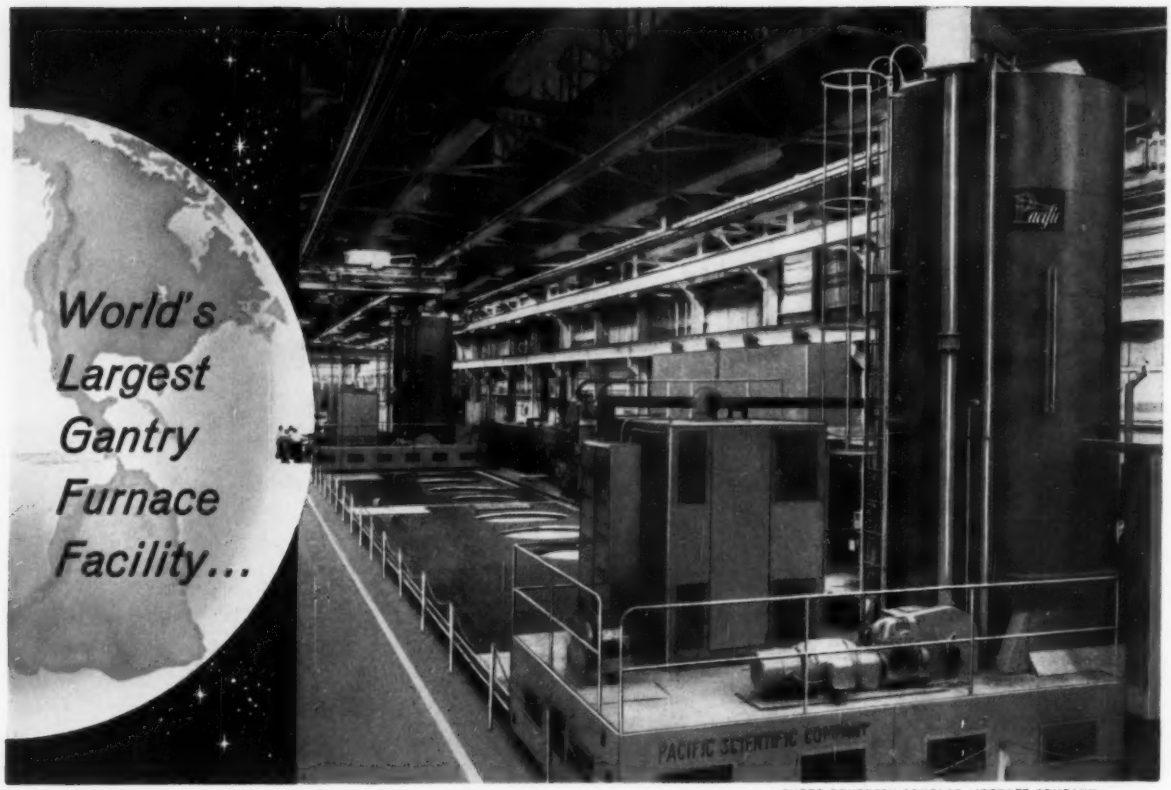
654. Low-Temperature Cabinets
Folder illustrates line of refrigeration equipment for producing temperatures to −140. *Revco Inc.*

655. Optical Pyrometer
"Pyro" optical pyrometer instantly measures temperatures of minute spots, fast moving objects, and small streams. Instrument ranges available from 1400 to 7500° F. Catalog No. 85, *Pyrometer Instrument Co.*

656. Gantry Furnace
Pacific Scientific Co. will send brochure covering heat treating equipment, including "dual-range" gantry furnace which heat treats both aluminum and steel alloys.

657. Bright Annealing
Pamphlet from *Drever Co.* details ad-

To request any item listed circle appropriate number on Reply Card, p. 48-B



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DESIGNED

BUILT AND INSTALLED FOR DOUGLAS AIRCRAFT COMPANY BY

Pacific
TRADE MARK

For the first time . . . anywhere in the world . . . two gigantic gantry furnaces on the same track serve any one of TEN PIT STATIONS! This towering installation by Pacific Scientific now in operation at the Douglas Aircraft Company's Torrance, California facility, operates on 157 feet of track. It is so completely automatic that only one operator is needed for each gantry.

Designed for rapid-production heat treating, large missile components are quickly transferred from furnace to furnace to quench tank, under precision controlled atmospheres and temperatures. Heated parts are shielded from air by pneumatically actuated sleeves which join the draw furnaces and quench tanks to the gantry furnaces during each successive phase of the heat treating process.

HUGE • SMALL • STANDARD • SPECIAL • There's a Pacific furnace for every heat treating requirement because Pacific engineers have the extensive, proved experience to recommend a standard or modified furnace, or to design a special new one, for any heat treating need known to industry. And as new techniques and processes become necessary, you can depend on Pacific's competent research and development staff to supply the logical, prompt solution. A qualified Pacific field engineer is always available to discuss any heat treating job in your plant... simple or complex, for plant or laboratory...without obligation. Phone or write for complete data on Pacific's highly diversified heat treating capabilities.

Free!

Big 12-page color catalog on Pacific furnaces... standard, modified and special designs... yours for the asking!

GAS OR ELECTRIC INDUSTRIAL HEAT TREATING EQUIPMENT

PACIFIC SCIENTIFIC COMPANY

Office and Factory: 6260 Chalet Drive, Bell Gardens, Calif.

Creative Development and Manufacturing in Furnace Design

SAN FRANCISCO
SEATTLE
PORTLAND, OREGON
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DENVER

PACIFIC SCIENTIFIC COMPANY, P.O. Box 22019, Los Angeles 22, Calif.

Please send me your new 12-page catalog and full information on Pacific Heat Treating Equipment.

Name _____

Company _____

Address _____

City _____ Zone _____ State _____

Circle 807 on Page 48-8

vantages of their continuous bright annealing furnaces for processing stainless strip and wire.

658. Thermostatic Bimetal

Booklet from *W. M. Chace Co.* contains design data and applications for thermostatic bimetal. Forty types are available in coil, strips and completely fabricated elements.

659. Process Controls

Brochure from *Barber-Colman Co.* covers "Wheelco Capacitrols," the ultimate in control instrument flexibility.

660. Refrigeration Equipment

A chill treatment stabilizes tools and gages made of alloy toolsteels or high-speed steel. Information from *Harris Refrigeration Co.*

661. Two-Color Pyrometer

4-p. brochure describes the "Shawmeter," an automatic pyrometer for indicating, recording or controlling temperatures of hot billets in motion or streams of molten metal, or vacuum melting operations. *Shaw Instrument Corporation.*

662. Induction Heating

52-p. handbook illustrates a wide range of induction heating equipment for hardening, brazing, forging, soldering, annealing, shrink fitting and crystal growing. *Induction Heating Corp.*

663. Combustion Indicator

Flyer from *Selas Corp. of America* gives the facts on "Qual-O-Rimeter" combustion indicator for control of heat processing. By monitoring all factors affecting flame characteristics, it indicates any changes in less than 5 sec.

664. Controlling Pyrometer

Bulletin No. 1298 discusses the single target "N-14 Pyrotroller," a two-position, temperature indicating-controlling pyrometer. *Alnor Instrument Co.*

665. Carbon Potential Controller

Data Sheet 23 illustrates carbon potential controller which continuously measures and controls the carbon potential of gas atmospheres in heat treating furnaces. *Rolock Inc.*

666. Oil Quenching Systems

Catalog from *Bell & Gossett Co.* covers "Hydro-Flo" oil quenching systems, self-contained units which heat and cool quenching oils.

667. Carburizing Furnaces

Bulletin P-59 is available from *Ipsen Industries, Inc.* covering production carburizing furnaces of any desired capacity.

668. Annealing Furnaces

Get the facts on "Power Convection" heat-processing equipment from *Surface Combustion Div.* Bulletin SC-182.

669. Hump Furnace

Bulletin HMB-60 discusses hump-type mesh belt furnaces which provide low dew-point atmospheres for continuous brazing, annealing and hardening operations. *Harper Electric Furnace Corp.*

670. Automatic Rotary Furnace

Pamphlet from *American Gas Furnace Co.* discusses automatic rotary furnace for small parts annealing at lower cost.

671. Thermal Systems

Pamphlet contains information on gas-actuated thermal systems which withstand extreme vibration and corrosion conditions. *Minneapolis-Honeywell.*

672. Gas Alloying

Illustrated brochure from *Lee Wilson Engineering Co.* discusses new open-coil process of gas alloying.

673. Temperature Controls

Leaflet G-25 reviews line of differential expansion temperature controls available from *Burling Instrument Co.* Specifications for each model included.

674. Temperature Crayons

Tempil Corp. has published information on "Tempilstiks," a simple and accurate means of determining temperatures.

675. Furnace Tubes

General Alloys Co. will send data on "Wrought-Cast" radiant tubes for consistent long life.

676. Temperature Control System

4-p. leaflet from *Atkins Technical, Inc.* describes their precision system for controlling temperatures within 0.2° C. up to 1200° C. (2200° F.).

677. High-Temperature Furnaces

Marshall Products Co. offers a booklet on electric furnaces for producing temperatures up to 2600° F.

678. Thermocouples

Thermocouple Catalog E-16 includes a "Thermowell" material guide for hundreds of industrial applications involving temperature measurement. *Thermo Electric Co.*

679. Heat Treating Equipment

Catalog 60 from *Stanwood Corp.* gives the facts on "Cor-Wal" heat treating containers and baskets.

Cleaning and Finishing Equipment

680. Ultrasonic Cleaners

L & R Manufacturing Co. will send data sheets illustrating the "Ultra-Clean 320 Series" of transducerized ultrasonic units for cleaning precision parts.

681. Paint Stripping

Bulletin F-7893 describes "Oakite Stripper S-A" which removes tough finishes such as epoxy coatings. *Oakite Products.*

682. Chromate Conversion Coatings

Pamphlet from *Allied Research Products* on "Iridite," a chromate conversion coating for nonferrous metals, easily applied at room temperature.

683. Solvent Degreasing

Detrex Chemical Industries, Inc. has published brochure "Solvent Degreasing —What Every User Should Know" by Dr. C. E. Kircher.

684. Tin-Zinc Plating

Hooker Chemical Corp. has published literature discussing plating with tin-zinc, tin, silver, or copper.

685. Paint Finishing

12-p. Leaflet PF-400 illustrates complete paint finishing system and component units and includes a section on strip-coating line. *Ross Engineering Div.*

686. Cleaning by Ultrasonics

National Ultrasonic Corp. has published a 12-p. ultrasonic cleaning primer which describes ultrasonic cleaning, and presents applications and metal cleaning principles.

687. Chemical Cleaner

Flyer from *Pall Corp.* gives the facts on their metal parts chemical cleaner which removes encrusted carbon, weld oxidation, brazing flux, varnish and paint from stainless steel and other metals and alloys. . . . No electronic or moving parts.

688. Hard Anodizing

4-p. pamphlet describes desk size multi-purpose electrolytic process unit for hard anodizing, plating or electrochemical milling. *Allen Aircraft Products, Inc.*

689. Bitumastic Coatings

8-p. Bulletin T97-61 on "Bitumastic"

Circle appropriate number on Reply Card, p. 48-B

Designed with Wall Colmonoy Stainless Brazing . . . A Case History:

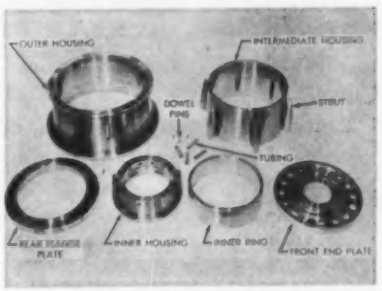
Brazing Speeds Building of Jet Engine Diffuser

The stringent design requirements of this diffuser assembly were met by stainless furnace brazing. The number of manufacturing operations were also reduced, cutting total cost.

The parts shown had to be joined for high performance service conditions. The Nicrobraz® stainless brazing filler metal used produced joints as strong as the parent metal.

Inaccessibility prevented machining after assembly, so allowable tolerance was only (plus or minus) .002". Precision application of brazing filler metal and of furnace temperatures kept distortion within the limits.

Call or write for more information about how our stainless brazing facilities can help you.



Wall Colmonoy Stainless Furnace Brazing Gave These Important Benefits:

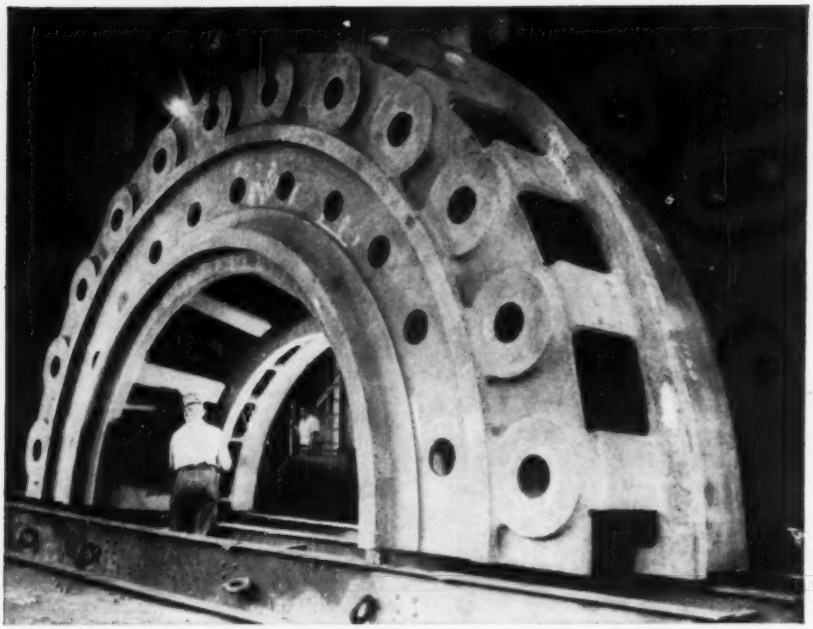
- **Brazed joints as strong as parent metal**
- **13 parts joined in one brazing operation**
- **Distortion held to within ±0.002"**
- **No finish machining was needed**
- **Brazed assembly was fully annealed**
- **No clean-up, assembly was bright and clean**

WALL COLMONOY CORPORATION
Stainless Processing Division
19345 JOHN R STREET • DETROIT 3, MICHIGAN

Representatives in all key industrial areas

PROCESSING PLANTS: Detroit, Michigan • Morrisville, Pennsylvania • Dayton, Ohio • Montebello, California

Circle 808 on Page 48-B



More Than Meets the Eye in "ELECTRICITY at YOUR FINGER TIPS" . . .

The author of this article is Joseph A. Shuffstall, General Manager of Administrative Services, Erie Forge & Steel Corporation, Erie, Pa.

Before throwing an electric switch, have you ever hesitated to give a fleeting thought to why electricity is your instant servant?

Here's a typical example of what is contributed by industry to make possible the enjoyment of your many electric servants. This 44 ton steel casting, made in the foundries of Erie Forge & Steel Corporation, Erie, Pa., is one of 12 half covers for 6 hydro-electric turbines, each of which will produce 150,000 kilowatts of electric power on the Lewiston Project near Niagara Falls, New York. Altogether, these six 200,000 horse power turbines will furnish 900,000 kilowatts and there are 19 more of smaller horse power on this project alone.

Now think of baking a batch of fluffy biscuits, a light, white loaf of bread, a birthday cake. The same procedures the baker follows are used by the foundrymen who cast these mammoth covers. First, skilled engineers and foundry technicians design and build the correct patterns for moulds, "the cake pans" into which the ingredients are poured, white hot molten steel. Then the ingredients, carefully measured and controlled by the metallurgists, must be exactly right to make sure the casting will do its job perfectly.

To get technical right here, the large 9 foot 6 inch bore core was made integral with the mould by aligning core box with sweep spindle and ramming it on bed of mould. This eliminated the necessity of transporting, handling and setting extremely large cores. A segmental type pattern with a ring type riser on the cope side eliminated the cope portion of the mould. Directional and progressive feeding of the molten metal during the solidification period was made possible by slight design modifications promoting a sound homogeneous structure.

After stripping, the castings were subjected to hydro-blasting and the arc-air method for excavating surface imperfections. Finally, rigid dimensional inspection was followed by magnetic particle and radiographic examination at critical areas.

Here, at Erie Forge & Steel, experienced engineers, metallurgists and craftsmen control quality every step of the way from raw materials to finished steel casting.

This short sketch covers only a small part of industry's contribution to the multitude of machines which, working as a unit, make "electricity at your finger tips" a commonplace and useful reality.

ERIE FORGE & STEEL CORPORATION

ERIE, PENNSYLVANIA

Circle 809 on Page 48-B

cold-applied protective coatings for a variety of corrosion and deterioration problems. *Koppers Company, Inc.*

690. Ultrasonic Cleaning Systems

Flyer from *Acoustica Associates, Inc.* contains specifications and price list on line of ultrasonic cleaning systems, ultrasonic generators, transducerized tanks, complete systems and immersible transducers.

691. Selector Chart

MacDermid Inc. will send selector chart which enables a metal finisher to match proper chromate coating to the type of finish desired.

692. Disposable Filters

The Cuno Engineering Corp. will send bulletin MW-100 describing "Micro-Wynd" disposable filter packages for filtering plating solutions and chemical process streams.

693. Nickel Sulfamate Process

Hanson - Van Winkle - Munning Co. offers a 16-p. technical instruction manual on Nickel Sulfamate process, for electroplating, electroforming, and resizing by metal build-up.

694. Blast Cleaning

8-p. Pamphlet No. 227A illustrates line of "Rotoblast" units designed to meet specific blast cleaning requirements yet suitable for general application. *Pangborn Corporation.*

695. Conversion Coatings

Phosphating reference chart and detailed information on "Paintite" and ten other phosphating and conversion coating processes is available from *Turco Products, Inc.*

696. Abrasive Grain

Norton Co. will send information on No. 23 "Alundum" abrasive grain for precision grinding operations such as surfacing with abrasive segments.

697. Glass Shot

Brochure from *Microbeads, Inc.* discusses "Glas-Shot," microscopic glass beads for use with all types of wet or dry blast cleaning equipment.

698. Ultrasonic Degreasing

Detrex Chemical Industries, Inc. has a leaflet which discusses "Soniclean" equipment for ultrasonic cleaning and degreasing applications.

Welding and Joining Equipment

699. "Edgegraphing"

16-p. data sheet explains Edgegraphing, a new technique for hand analysis of complex engineering data in 10, 20, or more variables. *Statistical Engineering Institute.*

700. Hardness Testing

Reference book containing complete information on hardness testing. Easy-to-read text with many illustrations. *Clark Instrument, Inc.*

701. Testing of Metals

Ten-page Bulletin M-2 from *Instron Engineering Corp.* covers all fields of precision metals testing.

702. Plasma Spraying

Folder entitled "Plasma Bond Spraying Service" describes applications and fabrication techniques for metallic-ceramic coatings. *Thermal Dynamics Corp.*

703. Electron Beam Welding

The *NRC Equipment Corp.* will send information on electron beam welding, to help solve your tough welding problems.

704. Stainless Brazing

Wall Colmonoy Corp. has information on "Nicrobraz" for brazing complex stainless steel parts in one operation.

705. Flame Plating

Series of bulletins prepared by *Linde Co.* present up to date physical data and characteristics of various flame-plated coatings, including tungsten carbide-cobalt coatings.

706. Controlled-Angle Welding

Folder WC-60 from *Falstrom Co.* describes controlled-angle torch, for tungsten inert-gas arc welding, featuring a completely flexible head.

707. Power Supplies

Glenn Pacific Power Supply Corp. has literature on "Variable Slope" constant voltage power supplies for all consumable electrode automatic and semi-automatic welding processes.

708. Silver Brazing

Bulletin 20 details the advantages of silver alloy brazing of ferrous or non-ferrous components using "Easy-Flo 45." *Handy & Harmon.*

709. Welding Positioners

Ransome Co. has published a 16-p. "Guide to Positioning Equipment" which includes a discussion of the advantages and kinds of equipment available.

710. Structural Adhesives

Brochure discusses "Lefkoweld" adhesives for bonding metal, ceramics, glass, wood, plastics and hard rubber. *Leffingwell Chemical Co.*

711. Seam Welder

8-p. Bulletin 320-8 describes the "Type MPT-2" seam and roll spotwelder which operates on 3-phase current. It is an air-operated press-type unit. *Sciaky Bros.*

712. "Welding News"

Quarterly published by *Ampco Metal, Inc.* is directed to users and potential users of bronze electrodes.

713. DC Welder

Bulletin NH-182 from *National Cylinder Gas Div.* discusses diesel engine "Model SDD-250 DC" welder with a rated output of 250 amp. at 40 volts.

714. Power for Welding

Bulletin AC-60-1 from *Cristie Electric Corp.* describes line of power supplies in d-c. voltage ranges up to 135 volts, and amperage ranges from 15 to 1500 amp.

715. Brazing Furnace

Details on "Model LAC 200 Series" conveyor brazing furnace given in Bulletin 5711A. Temperatures up to 3400°F. *C.I. Hayes, Inc.*

716. Projection Welding

20-p. Brochure SP-27 "Projection Welding With Embossed Projections" gives data on projection-welding techniques, projection-forming tools, welding electrodes and joint design. *Taylor Winfield.*

717. Plasma Coating

12-p. booklet illustrates the plasma coating process, and presents properties and uses of coatings. *Plasmatech Div.*

718. Shape-Cutting Machine

8-p. Booklet No. F55-040 describes the "Oxweld CM-56" cutting machine. Intricate metal parts can be produced from simple pencil sketches. *Linde Co.*

719. Hard Surfacing

4-p. data sheet "Hard Surfacing Austenitic Manganese Steel With Colmonoy" is available from *Wall-Colmonoy Corp.*

Inspection and Control

720. Roughness Meter

Flyer from *Cleveland Instrument Co.*

Circle appropriate number on Reply Card, p. 48-B

A TESTING PROGRAM? . . . OR "JOB"?

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Reputedly, the finest and most completely equipped independent Testing Laboratory on the Pacific Coast

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APPROVED BY MAJOR AIRCRAFT COMPANIES . . . and OTHER LARGE CORPORATIONS IN AND OUT OF THE STATE . . . TO HANDLE THEIR TESTING!

Circle 810 on Page 48-B

INTERNATIONAL SILVER ANNEALS 35,000 LBS. OF BRASS & CUPRO-NICKEL A DAY

in these Power Convection bases

One man is now as productive as many 2-or-3 man annealing departments, and the tools that make him so valuable are these Surface Power Convection* annealing bases. Along with his production rate of 35,000 lbs. a day, he gets exceptional quality in his finished brass and cupro-nickel coils. Power Convection equipment never lets the temperature vary more than 10°F from top to bottom of a load. While one load is heating or soaking, a second is cooling, and the operator prepares the third load on its tray. A single crane handles all loading and unloading.

All the operator does to start a heating cycle is make a single electrical connection between cover and base. The International Silver Company, Meriden, Connecticut, is one of many manufacturers who are realizing higher earnings from Surface Power Convection equipment. You can be another, simply by calling Surface Combustion, 2377 Dorr Street, Toledo 1, Ohio. In Canada: Surface Industrial Furnaces Ltd., Toronto, Ont.

*Trademark of Surface Combustion, Division of Midland-Ross Corp.

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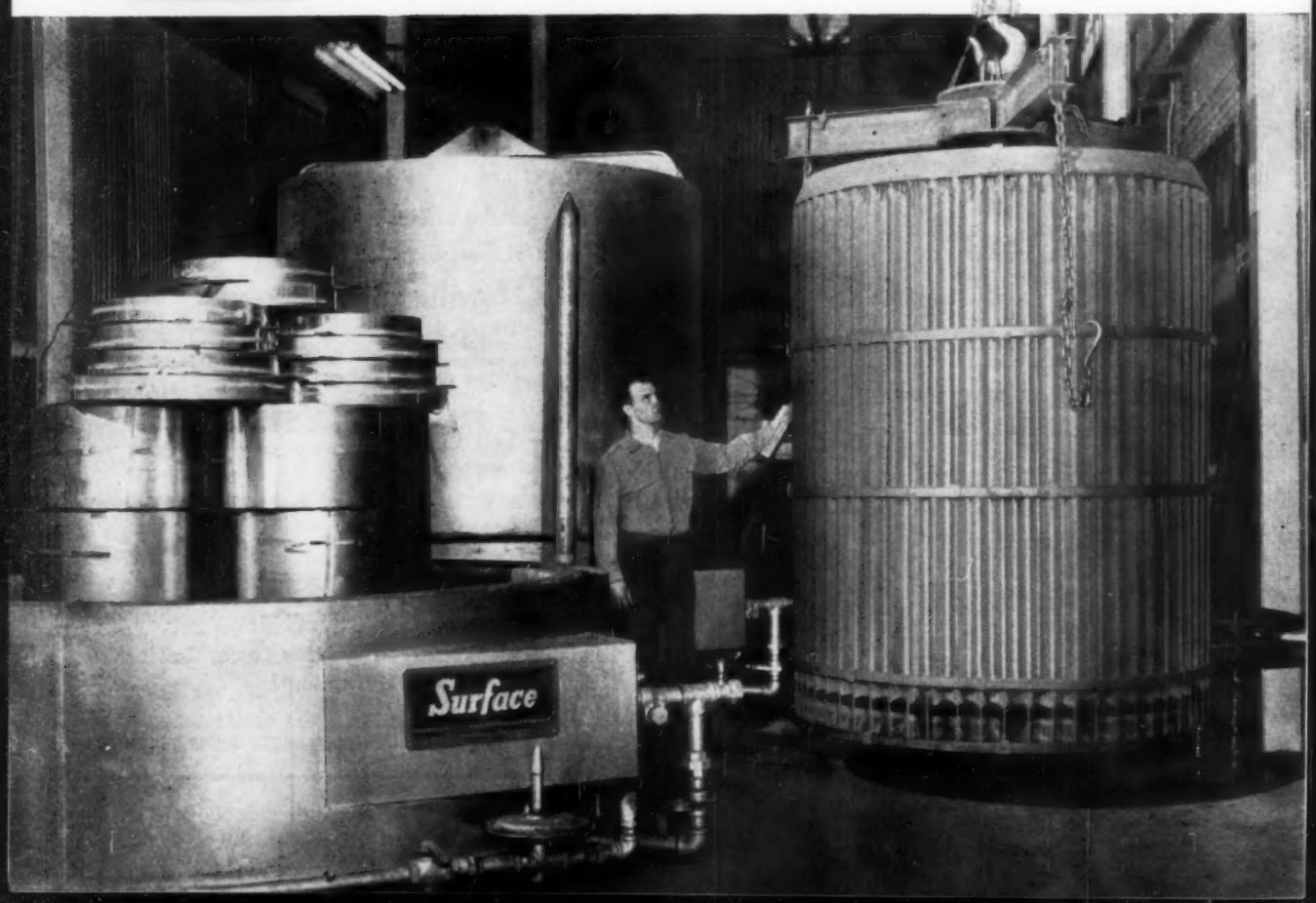


gives the facts on their roughness meter, a precision instrument for measuring roughness in the shop, the inspection department or laboratory.

721. Metallurgical Microscopes

Catalog 2K from *Unitron Instrument Co.* covers complete line of metallurgical microscopes and accessories for research, industry and education.

722. Electrolytic Polisher

The *Ercona Corp.* will send pamphlet discussing the Carl Zeiss Jena electrolytic polisher, which permits constant observation of the etching process.

723. Universal Tester

Riehle Testing Machine Div. will send bulletin on universal testing machine, featuring electrobalanced indicating unit and instrumentation.

724. Facilities Catalog

Metrol Labs, Inc. has published information listing facilities, including ultrasonic and X-ray inspection, spectrographic analysis, and creep-rupture evaluations.

725. Magnetic Particle Inspection

Pamphlet from *Picker X-Ray Corp.* describes magnetic particle inspection techniques, including "Ferroscope," "Ferroflux" and "Portaflux."

726. Superficial Tester

Catalog RT-48 gives complete information on the superficial tester as well as a full line of Rockwell hardness testers. *Wilson Mechanical Instrument Div.*

727. Gamma Radiography

Bulletin from *Budd Instruments Div.* on "Iriditron" unit, which can hold as much as 30 curies of iridium-192.

728. Information Searching

Brochure discusses documentation service which delivers the world's current metallurgical literature to you every two weeks in digest form. *American Society for Metals.*

729. Processing X-Ray Films

Eastman Kodak Co. will send wall chart which recommends proper tank-processing procedures for X-ray film.

730. Spectrographic Equipment

Identify and analyze trace elements beyond question with 1.5 meter and dual grating spectrographs. Catalog D-277 from *Bausch & Lomb.*

731. Horizontal Goniometer

The *Radio Corporation of America* has published literature on X-ray diffraction and spectroscopy equipment.

732. Autographic Plotters

Brochure PG-100 contains application data and complete specifications on standard, high-speed, and extra-high speed strain gage plotters; modular plotters; segmental recorders and scanner plotters. *Gilmore Industries, Inc.*

733. X-Ray Protection

36-p. booklet from *Ameray Corp.* contains drawings and specifications for effective X-ray shielding in accordance with established radiation protective codes.

734. Plastic Lenses

4-p. Bulletin 100 discusses advantages, applications and specifications for lightweight, optically ground and polished plastic lenses. *Fostoria Corp.*

735. Laboratory Instruments

16-p. Apparatus Review No. 12 illustrates many laboratory instruments from *LaPine & Co.*—spectrophotometers, pH meters, electrobalances, recorders, and related equipment.

736. Liquid Level Switch

Acoustica Associates, Inc. has issued a folder on its unitized liquid level switch which combines an ultrasonic probe and a transistorized control.

737. Metallurgical Apparatus

8-p. brochure from *Buehler Ltd.* illustrates metallurgical apparatus including cutters, grinders, mounting presses, portable and table-mounted polishers and electrolytic etchers and cleaners.

738. pH Meter

Beckman Instruments Div. has published a bulletin describing the "Zeromatic" pH meter, a line-operated, drift-free instrument for making precise pH or millivolt measurements.

739. Measurement Facilities

4-p. leaflet from *General Electric*, GEA-7013, describes electrical-physical measurement facilities available at Schenectady Instrument Service Dept.

740. Metallurgy Courses

32-p. catalog describes courses available through Metals Engineering Institute. Individual home-study or in-plant "extension" courses include elementary metallurgy, heat treating, welding and foundry operations. *American Society for Metals.*

741. Dye Penetrants

4-p. folder describes 16-mm. film on inspection, "How to Locate Flaws With Dye Penetrants" (23 minutes, sound and color). *Turco Products, Inc.*

742. Hardness Testing

Clark Instrument, Inc. will send free reference book covering hardness testing. Hardness conversion chart also available.

743. Radiography Equipment

Curtiss Wright Corp. will send pamphlet on "Fedrex" radiography equipment, available in 140, 160, 200 and 260 kv models.

744. Coarse Grinders

The AB Metal Digest, Vol. 6, No. 5, contains a good discussion of a variety of coarse grinders for metallographic applications. *Buehler Ltd.*

745. Thickness Gages

Bulletin from *Branson Instruments, Inc.* sets forth details on "Audigage" and "Vidigage" portable thickness testers which measure from one side only and cover a wide thickness range.

746. Research Microscopes

Pamphlet describes "Cooke M12" metallurgical microscope. Superior optical performance and added convenience. *Cooke, Troughton & Simms, Inc.*

Production and Casting Equipment

747. Pelletizing Discs

4-p. pamphlet reviews *Dravo Corp.'s* line of rotating discs for pelletizing and mixing material such as ore fines, phosphates or ceramic clays.

748. Diffusion Pumps

12-p. catalog contains information on diffusion and booster pumps . . . also speed curves for models ranging from 1 to 32 in. *NRC Equipment Corp.*

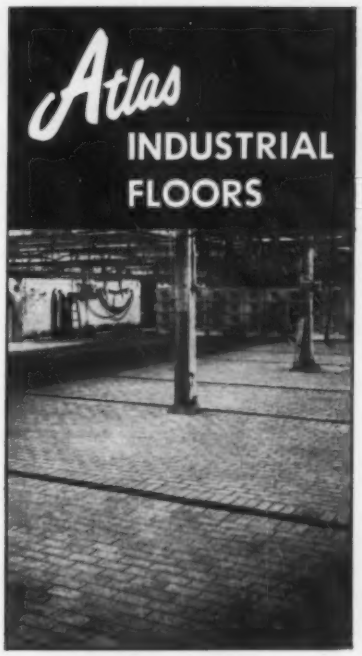
749. Atmosphere Analyzer

Booklet from *Perkin-Elmer Corp.* discusses furnace analyzer which automatically records volume percent for each of the four gases—O_2, CO, CO_2 and CH_4—or combinations of these.

750. Vacuum Pumps

Brochure from *F. J. Stokes Corp.* covers

Circle appropriate number on Reply Card, p. 48-B



▸ stop corrosion

▸ resist wear

▸ eliminate maintenance

To permanently stop corrosive action, not merely retard or control it, install Atlas industrial floors. These floors are resistant to the widest range and concentrations of acids, alkalies, salts and solvents. And they are engineered to withstand all types of physical abuse from heavy static loads to constant truck traffic.

Atlas industrial floors are constructed of acid brick laid on an impervious membrane and joined with one of Atlas' six standard, corrosion-proof cements. This wide choice enables a floor to be designed to meet specific service requirements.

Make an Atlas floor your maintenance-free, corrosion-proof base of operations.

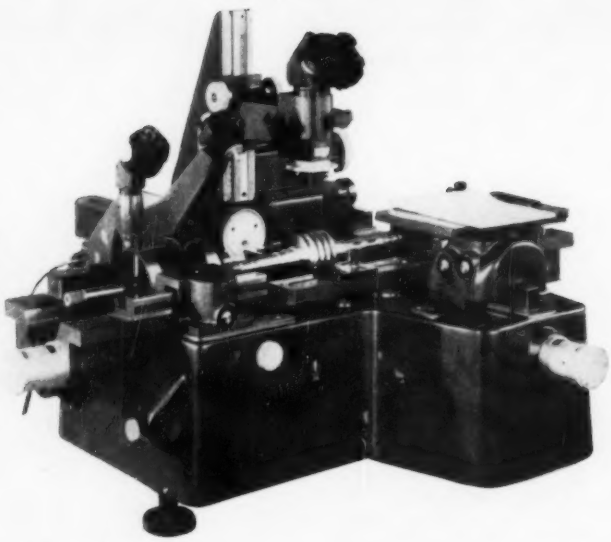
Write for Bulletin 3-3 giving complete details.

Atlas MINERAL PRODUCTS COMPANY

DEPT. MP, MERTZTOWN, PA.

Subsidiary of
Electric Storage Battery Company

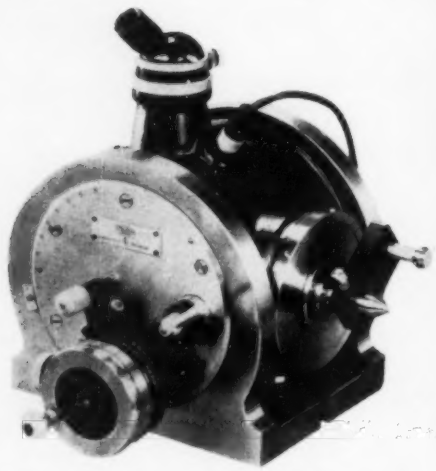
Circle 812 on Page 48-B



LARGE TOOLMAKER'S MICROSCOPE

This versatile inspection and production measuring instrument is extremely rugged, accurate and simple to operate. Flexibility is enhanced through use of numerous accessories. Areas of application include measurement of length, angles, screw threads and contours.

Technical Data: Measuring range 6 x 2 in. • Micrometers read to 0.0001 in. • Angular scale of goniometer ocular 1 min. • Diameter of circular stage 11 in. • Magnifications 10x to 50x



OPTICAL DIVIDING HEAD — MODEL 130

This sturdily constructed, precision instrument measures angles in the order of 10 sec. of arc (5 sec. by estimation) utilizing a newly developed scale which permits extreme accuracy and repeatability of readings. The model 130 may be used as an inspection instrument or on surface grinders, millers and drill presses without any loss of accuracy. The wide range of applications include cam shaft inspection when the instrument is used together with the Abbe measuring unit.

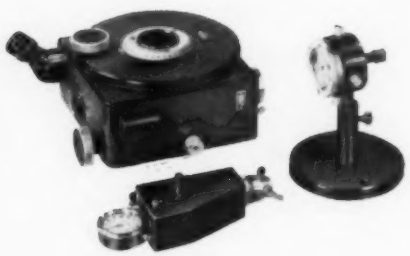
CARL ZEISS JENA

companion of scientific progress for six generations

UNIVERSAL MEASURING MICROSCOPE

The perfect laboratory and production instrument for a variety of precise measuring techniques including a wide range of applications from simple linear measurement (internal and external) to intricate coordinate measurement. Accessories permit lead screw and cam shaft inspection as well as concentricity and taper measurement.

Technical Data: Measuring range 8 x 4 in. • Precision glass scales read to 0.00005 in. • Can be read by estimation to 0.00001 in. • Scale of accessory rotary table to 30 sec. • Angular scale of goniometer ocular 1 min. • Magnifications 10x to 50x



ANGLE DIVISION TESTER — ONE SEC.

The newly designed Zeiss Angle Division Tester is used to check and measure angles with a high degree of precision. Among its many applications are checking dividing heads, rotary tables, gears, polygons, etc. It may also be used in setting angles for the manufacture of index plates, gears, slotted discs and circular scales.

Technical Data: Fine scale reads to 1 sec. • Glass graduated scale reads to 10 min. • Coarse graduated scale reads to 1 deg.

Complete information may be obtained from your local Carl Zeiss Jena instrument dealer or by writing: Dept. MP 2/61

ERCONA **Ercona Corporation, Scientific Instrument Division, 16 West 46th Street, New York 36, N.Y.**
In Canada: Jena Scientific Instruments Ltd., 1437 MacKay Street, Montreal, Quebec

Circle 813 on Page 48-B

complete line of "Series H Microvac" pumps. Free vacuum slide calculator also available.

751. Alloy Steel Castings

Leaflet No. 300 from *Alloy Steel & Metals Co.* presents the design advantages and engineering properties of "T-1" alloy steel castings, plus welding and machining data.

752. Melting Furnaces

The *DaPrato Mfg. Co.* will send literature describing "Calamari" low-frequency induction furnaces. Four basic types cover all types of ferrous and nonferrous melting applications.

753. Castable Refractory

H. K. Porter Co. has issued a pamphlet on "Firmcast," a hydraulic castable refractory for use up to 2400° F.

754. Ramming Mixes

Literature on "Magnaram 85" and "Magnaram 95"—air setting, periclase ramming mixes for application in electric furnaces, openhearths, and ladles. *H. K. Porter Co., Inc.*

755. Dewpoint Indicators

Flyer from *Weighing & Control Components, Inc.*, No. DPI-4, offers details on accurate, portable dewpoint indicator. Measures dewpoint temperatures as low as −100° F. (0.0003% moisture by volume in air).

756. Fluorspar Briquet

Glen-Gery Shale Brick Corp. will send information on their "Glen-Spar" fluorspar briquet (with a certified purity of no less than 95 effective units) for steel melting operations.

757. Ammonia Dissociator

Catalog Section 25 from *Rolock Inc.* illustrates ammonia dissociator that includes flow diagram and construction details.

758. Standard Meehanite Shapes

12-p. booklet outlines standard sizes and shapes of Class A Meehanite castings. Available shapes include round solid bars, round cored bars, square and rectangular bars, and round and rectangular plate. *The Greenlee Foundry Co.*

759. Vacuum Ovens

30-p. product catalog presents information on "VacU-Therm" vacuum and radiant ovens, dri-box vacuum bake systems, and controlled atmosphere enclosures. *Temperature Engineering Corp.*

760. Refractories

Periodical from *The Carborundum Co.* presents news of refractories applications. October 1960 issue features "Refractory Materials of Construction."

761. Scrap Briqueting Press

Pamphlet BP-217 illustrates a line of scrap briqueting presses for converting chips, turnings and borings into high grade scrap. *Milwaukee Foundry Equipment Div.*

762. Metallurgy Courses

32-p. catalog describes courses given by Metals Engineering Institute. Individual home-study or in-plant "extension" courses include elementary metallurgy, heat treating, welding and foundry operations. *American Society for Metals.*

763. Button Furnace

NRC Equipment Corp. will send information on vacuum arc furnace for button melting by cold-mold (consumable or nonconsumable) techniques.

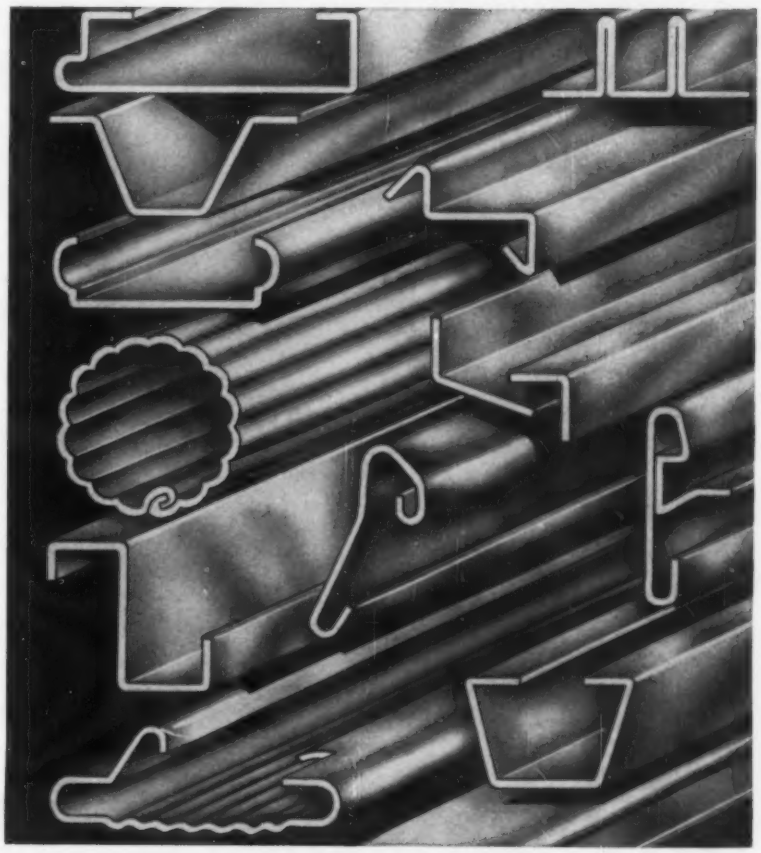
764. Manganese In Aluminum

Union Carbide Metals Co. has published "Manganese Puts Muscle in Aluminum" in the Winter 1961 issue of U.C. Metals Review.

765. Vacuum Sintering Furnace

Consolidated Vacuum Corp. offers Bul-

MONEY SAVERS...



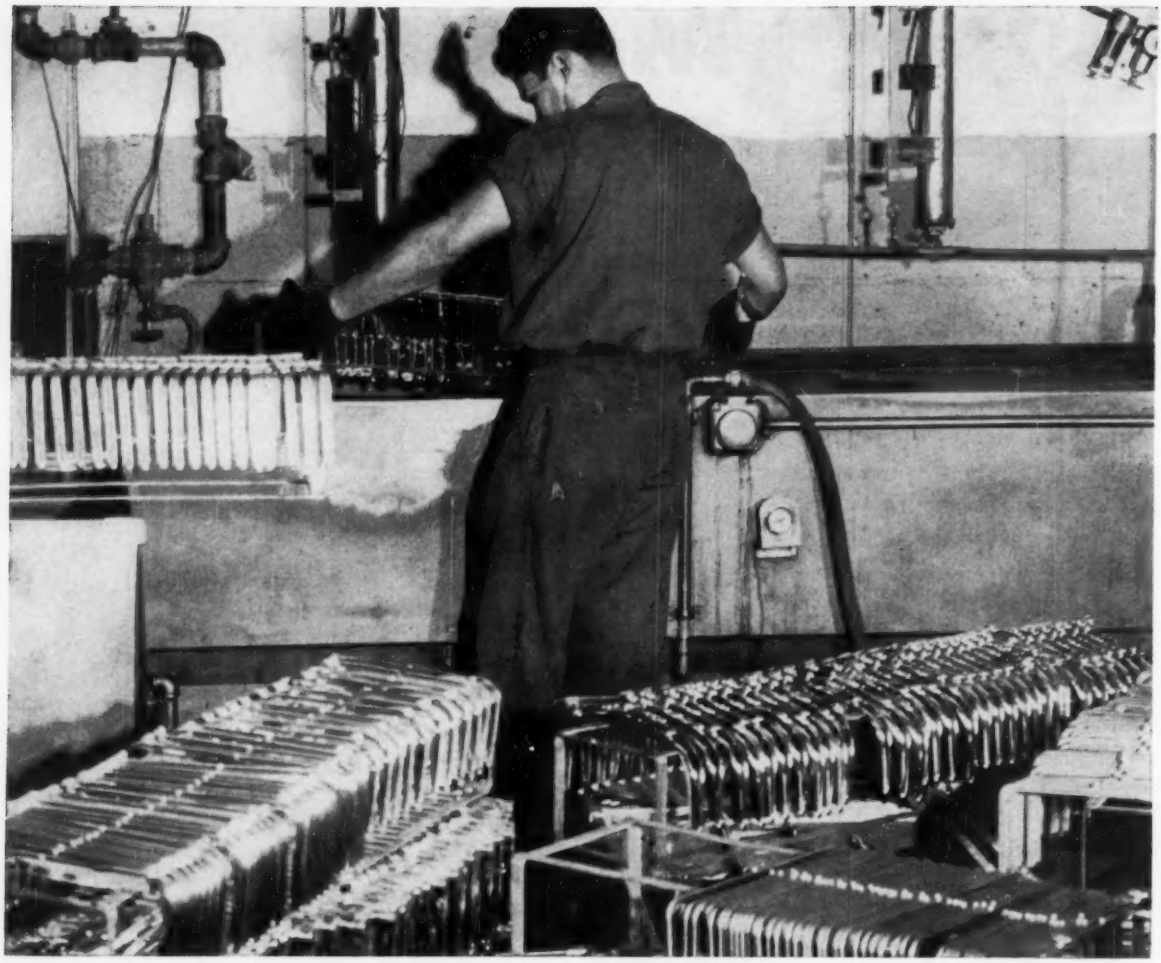
• High-speed roll forming techniques which incorporate punching, notching, embossing or other secondary operations can drastically cut your metal shapes costs. The shape you need may already be in stock at Roll Formed. Check Roll Formed Bulletin 760 for existing shapes and see how Roll Formed's skills can help you cut costs and give you deliveries keyed to your production schedules.

SEE OUR CATALOG IN SWEET'S

ROLL FORMED PRODUCTS COMPANY

MAIN OFFICE AND PLANT
3761 OAKWOOD AVE., YOUNGSTOWN, OHIO

Circle 814 on Page 48-B



Metgal Novelty Company, Richmond Hill, L. I., degreases metal handbag frames.

302,400 PARTS BEFORE CLEANOUT

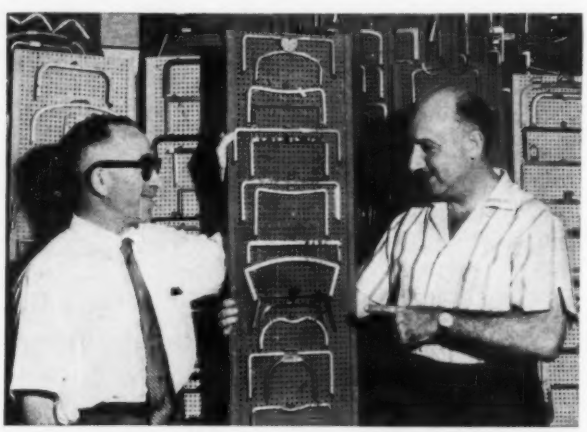
Metgal Novelty Company degreases thousands of metal handbag frames each week with Nialk® TRICHLORethylene.

It's not a simple cleaning job. Besides grease, they have to remove insoluble buffing compounds from the work. The metal might be brass, steel, plated copper or nickel plate.

The tanks "never go acid," says Sal Romano, co-owner. The stabilizer in Nialk TRICHLOR has *psp*—permanent staying power. It lasts, doesn't weaken between cleanouts. Since they get complete recovery of stabilizer on cleanout, they never have to add fresh stabilizer.

Regular tank checks are important to Metgal, too. Romano says, "Hooker and its local distributor, H. Harrington & Company, keep an eye on our operation so there is no undue loss of solvent."

Regardless of the metals you're working with, Nialk TRICHLOR can help solve your cleaning problems and save you money. Hooker's experience is yours for the asking. Call or write us about your problems or see your chemical distributor.



Henry Green (left), designer for H. Margolin & Company, leading handbag producer, and Richard Romano, Metgal co-owner, look over a display rack of handbag frames.

HOOKER CHEMICAL CORPORATION
402 Union Street, Niagara Falls, New York

Sales offices: Buffalo Chicago Detroit
Los Angeles New York Niagara Falls
Philadelphia Tacoma Worcester, Mass.
In Canada: Hooker Chemicals Limited, North Vancouver, B.C.

HOOKER CHEMICALS PLASTICS

Circle 815 on Page 48-B

letin 4-25 covering the "Heraeus" induction sintering furnace for producing temperatures up to 3000° C. in vacuum.

766. High-Vacuum Equipment

Catalog from *Vacuum-Electronics Corp.* reviews a complete line of high-vacuum equipment—leak detectors, evaporators, systems and components.

767. Fiber Insulation

Data Sheet IN-283A contains information on "Cerafelt," a light weight refractory fiber insulation. Recommended uses and advantages included.

768. Gating Zinc Die Castings

American Smelting and Refining Co. has a 48-p. booklet describing techniques of gating zinc die castings; multiple cavity arrangements and runner and sprue details included.

769. Vacuum Equipment

Bulletin 4510 contains information on vacuum equipment for metal purification, degassing, melting, alloying, sintering and brazing. *Kinney Vacuum Div.*

770. Aluminum Melting Furnace

"Ajaxomatic" furnace supplies molten aluminum to die casting machine in any size "shot" on a precise time cycle. *Ajax Magnethermic Corp.*

771. Grainal Alloys

Vanadium Corp. of America has published "Vancoram Grainal Alloys," which are efficient intensifiers for improving the hardenability of boron-containing constructional steels.

Parts, Forms, Shapes

772. Heli-Coil Inserts

Bulletin 770A from *Heli-Coil Corp.* discusses new "Miniature Power" inserting tool for installing small sizes of stainless steel "Heli-Coil" inserts.

773. Stainless Floor Plate

Booklet from *Eastern Stainless Steel Corp.* on "Super Diamond" stainless steel floor plate . . . application and specification data included.

774. Metal Hose

Catalog No. 539 illustrates line of flexible metal connectors in carbon and stainless steel. *Cobra Metal Hose.*

775. Capillary Tubing

8-p. Pamphlet No. 110 from *Superior Tube Co.* contains data on tubing for gas chromatography, including standard capillary, miniature and packed tubing.

776. Socket Screws

The Holo-Krome Screw Corp. has issued a leaflet on "Thermo-Forged" socket screws, guaranteed to meet or exceed any or all recognized industry standards.

777. Lock Nuts

24-p. Catalog 592-A illustrates line of spring-tempered steel lock nuts. *Palnut Company.*

778. Industrial Wire Cloth

The Cleveland Wire Cloth and Mfg. Co. has issued a loose-leaf specification catalog on industrial wire cloth and screen. Includes reference data on screen characteristics.

779. Lock Washers

8-page booklet from *Illinois Tool Works* discusses "Shakeproof" lock washers and includes drawings, charts and photos showing "problem" applications.

780. Steel Products

12-p. manual outlines complete line of products from *American Chain & Cable Co.*, including welding, wire, hoists, valves, hardness testers and other industrial equipment and instruments.

781. General Plate Products

14-p. brochure from *Texas Instruments Inc.* describes line of general plate products, including clad and solid base metals, clad and solid precious metals, and thermostat metals.

782. Marathon Press Parts

Bulletin EP11 presents information on precision parts for extrusion presses. *Marathon Specialty Steels, Inc.*

783. Heat Exchanger Tubes

The *Babcock & Wilcox Co.* will send literature on job-matched "Lectrosonic" heat exchanger tubes for economical long life in heat exchangers.

784. Blanking Strip

6-p. leaflet describes "Hydro-Cam Smooth-Edge" blanking process for producing blanks from coil or strip stock in low-carbon steel, stainless steel, aluminum, brass and copper. *Hydro-Cam Engineering Co.*

785. Roll Forming

Solar Steel Corp. has released a folder on cold roll-formed products. Advantages include high strength-weight ratio, good surface finish and accurate and uniform shapes.

786. Metal Mesh Belts

130-p. reference manual illustrates line of metal mesh belts for continuous processing. *The Cambridge Wire Cloth Co.*

787. Tubular Products

Bulletin No. 12 from *J. Bishop & Co.* describes tubular products; sizes from capillary to 1 in. OD in a wide range of steels and superalloys.

788. Fastener Reliability

6-p. reprint offered by *Standard Pressed Steel Co.* is a guide to the selection and application of structural bolting for high-strength, high-temperature uses.

Circle appropriate number on Reply Card, p. 48-B

Cooke M12 metallurgical microscopes
give you superior optical performance . . .
new design for a new standard of convenience in use . . .
new versatility of application . . .
Model M12 BU, illustrated, 60X-1000X . . . $513.50
Send for more details on this and other models for
all routine and research techniques.

COOKE, TROUGHTON & SIMMS, INCORPORATED
91 WAITE STREET, MALDEN 48, MASSACHUSETTS • IN CANADA: 77 GREENVILLE STREET, TORONTO

Circle 816 on Page 48-B

Value analysis–

(nothing new to Armour Ammonia specialists)

For a great many years Ammonia specialists from Armour have been joining manufacturers at the conference table. The primary concern of these Armour men is to use their knowledge and experience with ammonia to help in the analyzation of metal products and heat-treating production methods.

Cost reductions, product improvements, labor-saving and safety procedures are a few of the many areas where the men from Armour may aid you. In addition, they can supply equipment lists, blueprints, and on-the-job supervision of ammonia storage equipment installations. Armour also offers informative technical bulletins and reports on the use and control of ammonia atmospheres.

Take advantage of this experience and service from Armour . . . the leader in the development of ammonia-derived atmospheres for heat treating. Buy Armour Anhydrous Ammonia—at least 99.98% pure when delivered . . . backed by technical service, whenever you need it, at no extra cost.

Ammonia Sales

Armour Industrial Chemical Company

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110 North Wacker Drive • Chicago 6, Illinois

Circle 817 on Page 48-B

The ASM is the communications center for technical information wherever metals are produced, processed, fabricated, designed, tested and applied. Metal Progress, monthly engineering magazine of the Society, reports on engineering developments in these 11 major technological areas:

FERROUS METALS

NONFERROUS METALS

HEAT- AND CORROSION-RESISTANT AND ELECTRICAL MATERIALS

RADIATION AND NUCLEAR MATERIALS & EQUIPMENT

TOOL MATERIALS, CUTTING AND FORMING EQUIPMENT

INDUSTRIAL HEATING EQUIPMENT AND SUPPLIES

CLEANING AND FINISHING EQUIPMENT AND SUPPLIES

WELDING AND JOINING EQUIPMENT AND SUPPLIES

INSPECTION AND CONTROL EQUIPMENT AND SUPPLIES

PRODUCTION AND CASTING EQUIPMENT AND SUPPLIES

PARTS, FORMS AND SHAPES FOR DESIGN AND APPLICATIONS

February, 1961 issue
METAL PROGRESS

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METAL PROGRESS
METALS PARK NOVELTY, OHIO

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Complete Reader Service Information With These Convenient Prepaid Cards

Catalogs and bulletins, new products and services and most advertisements in Metal Progress are numbered. To receive more information, circle the appropriate numbers on one of these postage paid cards. Editorial reprints will be sent free as long as they last.

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More Facts on Advertised Products. Because some advertisements cannot be numbered, please write the names of those advertisers in the blanks provided.

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Metal Progress February, 1961 issue

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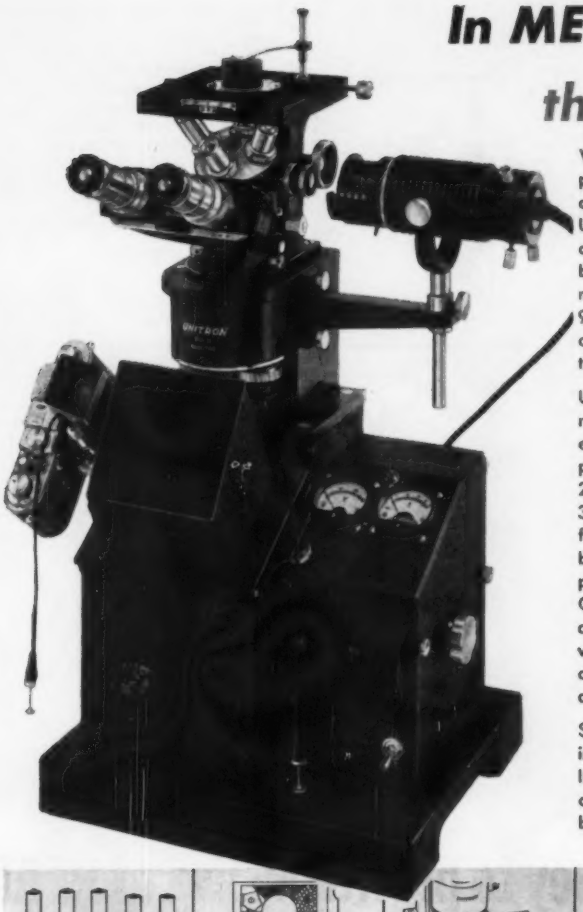
Cards not valid without company names, or if used after April 30, 1961.

In METALLOGRAPHS...

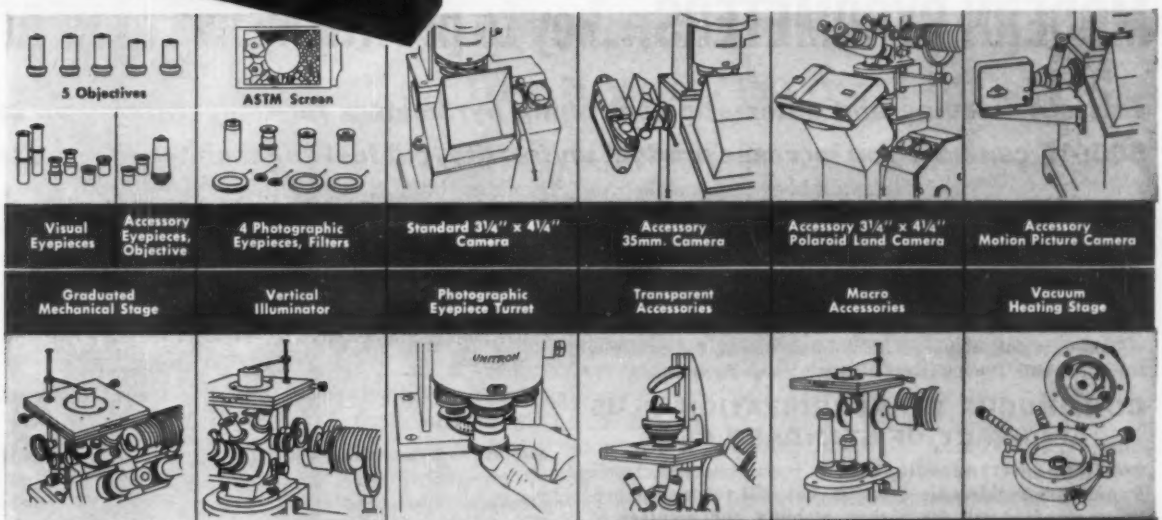
the trend is to UNITRON!



What do you look for when choosing a metallograph? All of the popular makes are precision instruments, are reasonably versatile and, to a varying degree, are easy to operate. But, except for UNITRON, all have the bulk of an office desk or optical bench and are tagged with a price that puts a substantial dent in the laboratory budget. UNITRON, and only UNITRON, offers a completely equipped metallograph in a compact and self-contained unit, taking only 9" x 12" of table space, which duplicates the performance of large cumbersome instruments — and at a price which is hardly more than the usual cost of a conventional metallurgical microscope.

Unlike the case with most metallographs, an adding machine is not required to compute its cost. Coated optics supplied as standard equipment include 5 objectives, 4 photographic eyepieces and 3 pairs of visual eyepieces. These give a magnification range of 25X-2000X. Also included in the purchase price are the built-in 3¼" x 4¼" camera and viewing screen; high-intensity illuminator for vertical, oblique, and transmitted light; variable transformer with both voltmeter and ammeter; accessories for transparent specimens; polarizing apparatus; filters; film holders; stage clips; cabinets etc. Optional extra accessories include Polaroid Land, 35mm. and movie camera attachments; low power (5X-40X) objectives for macro work; vacuum heating stage for temperatures to 1100°C and long working-distance 40X objective; ASTM Austenite grain size viewing screen and eyepieces; filar micrometer eyepiece; and additional optics.

Such a combination of features, versatility, convenience, and value is indeed unique with UNITRON. Little wonder then, that more and more laboratories are choosing UNITRON . . . from the large organization adding another metallograph to its equipment, to the small company buying an instrument for the first time.



FREE 10 DAY TRIAL

UNITRON's Metallograph and Universal Camera Microscope Model BU-11 with binocular eyepiece; objectives: M5X, M10X, M40X, 40X for transmitted light, 100X oil immersion; paired visual eyepieces: R5X, Ke10X Micrometer, Ke15X; photo eyepieces: 10X, 15X, 20X, Micrometer; etc., as described above.

$1379 f.o.b. Boston

Monocular Model U-11 **$1195**

UNITRON

INSTRUMENT COMPANY • MICROSCOPE SALES DIV.
66 NEEDHAM ST., NEWTON HIGHLANDS 61, MASS.

Please rush UNITRON's Microscope Catalog 2-L

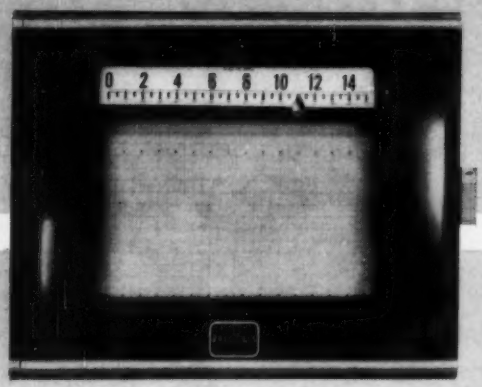
Name_____

Company_____

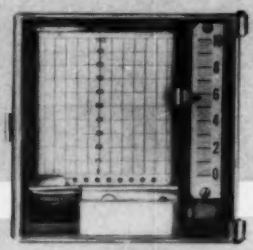
Address_____

City_____ State_____

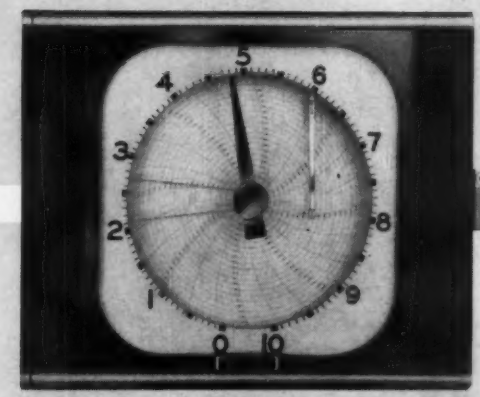
THE TREND IS TO UNITRON



Dynamaster Electronic Potentiometer Pyrometer—Strip-chart model records on chart 11" wide, 120' long.



Miniature Electronic Dynamaster Pyrometer—Records on 3" strip-chart. Indicator model features easy-to-read 9" scale length.



Dynamaster Electronic Potentiometer Pyrometer—Round-chart model records on 12" chart, indicates on extra large scale.

Bristol Millivoltmeter Pyrometers—Free Vane* pyrometer controllers (shown) or indicating types. Many control modes available.

MODERN PYROMETERS...key to profitable use of HEAT

Bristol recording and automatic controlling pyrometers for temperatures up to 5000°F can help you increase product uniformity, cut fuel and maintenance costs

Bristol makes a wide range of pyrometers for every requirement: Electronic potentiometers, millivoltmeter and radiation types . . . for furnaces, ovens . . . every type of heating equipment, every kind of fuel. The reliability and accuracy of these precision instruments have been proved in thousands of installations.

Take just one advanced Bristol instrument, for example, the Electronic Dynamaster* Potentiometer Pyrometer:

CONTINUOUS STANDARDIZATION PLUS ACCURACY OF STANDARD CELL

Continuous standardization in Dynamaster Electronic Pyrometers requires no dry-cells, **but still retains the precision standard cell for highest stability and accuracy of voltage reference.** Results: No interruption to operation, no batteries to change. And here are just a few of the Dynamaster types available:

A model for every requirement: Dynamaster Pyrometers are available as single-pen, two-pen, and multiple-record (up to 24 points) *strip-chart* instruments and as *round-chart* instruments.

Electric and pneumatic controllers: Both strip- and round-chart instruments are made in a very wide variety of controllers that meet every furnace and oven control requirement, including the following in a great many forms:

Electric Control—on-off, proportional input, 3-position, proportioning, proportional with automatic reset, and time-program.

Pneumatic Control—on-off, proportional, and proportional with reset.

Miniature Dynamaster Pyrometer: Full plug-in flexibility . . . takes only 5" x 5½" of panel space, but has same basic accuracy, same time-tested operating principle as full-size Dynamaster pyrometers described above. Ideal for graphic panels and centralized recording or indicating of large numbers of variables. Either electrical or pneumatic control types available.

Write for complete data on Bristol Pyrometers—and remember Bristol offers a complete line of thermocouples and pyrometer accessories. The Bristol Company, 106 Bristol Road, Waterbury 20, Conn. *T.M. Reg. U.S. Pat. Off.

BRISTOL... for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

Columbium flat-rolled steels

Do you need a steel, to use in the "as rolled" condition? Or a steel which has high strength, good weldability, good formability?

More and more manufacturers are turning to columbium flat-rolled steel products, for columbium sheet, strip or plate gives an answer to all of these requirements.

Here are just a few examples of columbium steel's wide versatility. Line pipe for gas and oil offers ease of manufacture with excellent physical strength. Trucks, automobiles, farm implements, trailers and railroad cars take advantage of strength and ease of formability. Pressure vessels utilize the deep-drawing qualities of the steel. These applications and many others tell the story of columbium steel's versatility—and all with fewer rejects.

In the face of mounting manufacturing costs, columbium steels offer hope of effecting economies in producing your products. Ask any steel company for they can make it. Or ask us—we have a wide experience in its uses and knowledge of its manufacture.

MOLYBDENUM

CORPORATION OF AMERICA

1312, Building Number 4, Gateway Center, Pittsburgh 22, Pa.

Offices: Pittsburgh, Chicago, Los Angeles, New York, San Francisco
Sales Representatives: Brumley-Donaldson Co., Los Angeles, San Francisco
Subsidiary: Cleveland-Tungsten, Inc., Cleveland
Plants: Washington, Pa., York, Pa.

Circle 820 on Page 48-B

KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many who may find it useful to review fundamentals from time to time.

Methods of Carburizing Alloy Steels

Carburizing is a means of impregnating the surface of steel with carbon, usually to very limited depths. Its purpose is to provide a hard, wear-resisting "case," or outer shell. Alloy steels, correctly handled, can be case-hardened without sacrificing desirable core properties.

There are three types of carburizing in general use:

Liquid Carburizing—The medium here is a hot-salt bath composed basically of cyanide compounds. The steel is immersed in the bath, the period of immersion depending upon the analysis of the steel and the depth of case desired. Liquid carburizing is a convenient method of producing thin, hard, wear-resisting cases, generally within the depth range of 0.02 to 0.03 in. However, deeper cases may be obtained, the actual depths depending upon economics and end uses.

Gas Carburizing — This method employs a furnace in which a carbonaceous atmosphere is created; i.e., gases that are high in carbon components, or those containing carbon. Steel subjected to gas carburizing can be case-hardened to depths generally ranging from 0.01 to 0.04 in. When quenching takes place immediately after carburizing, distortion can be kept to a minimum.

Pack Carburizing — Where the pack method is used, the parts to be carburized are buried in a container of dry carbonaceous materials. The container is sealed tight to prevent the infiltration of air, placed in a furnace and kept there for eight hours or more, the actual time depending upon the depth of case desired. Pack carburizing is particularly suitable where a deep case is essential (0.06 in. and over), although medium cases in the 0.04-to-0.06-in. range are possible.

This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
Export Sales: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

Circle 821 on Page 48-B

What HORACE DREVER has to say about Lindberg heat treating equipment

Mr. Horace Drever, internationally prominent in the industrial heating field, is a Past-President of the Furnace Manufacturers Association and President of Drever Company, furnace manufacturers and commercial heat treaters.

QUOTE from Mr. Drever's unsolicited letter to Lindberg Engineering Company

"For the past three and one-half years, we have been operating one of your Type 243618 GVRT Furnaces along with a 500 CFH Lindberg Hyen generator in our commercial heat treating division. We are extremely pleased, not only with the fine quality of work turned out by this equipment but also its relatively trouble-free operation. As evidence of our complete satisfaction we have ordered another Lindberg Furnace of this type."

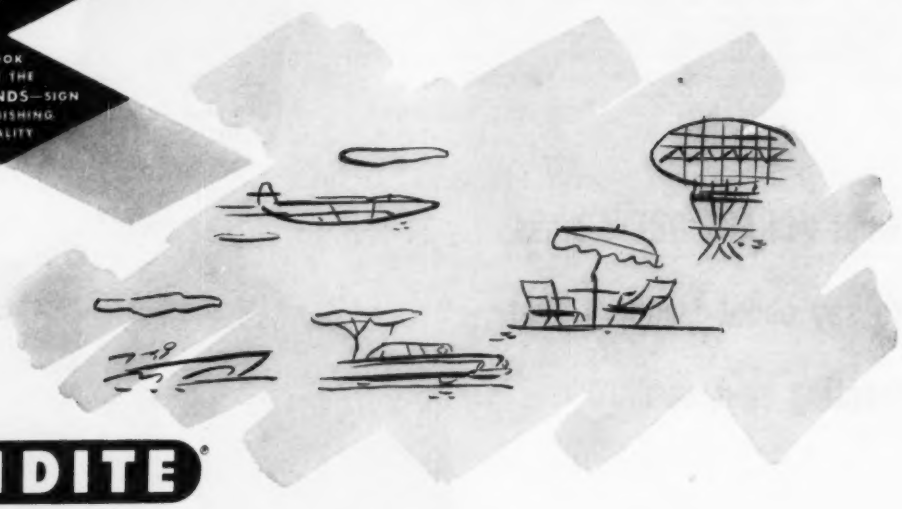
Lindberg Furnaces in operation at the Drever Company, Bethayres, Pennsylvania.

We are happy that Mr. Drever, a furnace manufacturer in his own right, originally chose Lindberg equipment for his heat treating plant and that its satisfactory service prompted an additional order. The second Lindberg Furnace is now in production at Drever Company, as the adjacent photo shows. Bless those satisfied customers! If you have a product or process in the metal or ceramic field requiring the application of heat you can depend on Lindberg's engineering and design know-how to provide exactly the right equipment to answer your need. Get in touch with your nearest Lindberg Field Representative (see classified phone book) or write direct to Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois. Los Angeles plant: 11937 South Regentview Avenue, Downey, California. In Canada: Birlefco-Lindberg, Ltd., Toronto.

LINDBERG
heat for industry

Circle 822 on Page 48-B

LOOK FOR THE DIAMONDS—SIGN OF FINISHING QUALITY



Only

IRIDITE®

Process Engineered

Chromate Conversion Coatings

Give you 5 additional benefits for Corrosion Protection—Paint Base—Decorative Finishing

1 A COMPLETE PROCESS ENGINEERED LINE

Developed for specific applications, there is an Iridite to provide the finish you desire, fit the equipment you have available and give the performance you require. Most Iridite coatings meet rigid military and civilian specifications.

2 EXPERIENCED TECHNICAL SERVICE

Our large field engineering staff is thoroughly familiar with chromate conversion coatings and related finishing operations. They'll help you check every step in your finishing operation to make sure you're getting the best possible finish on your products.

3 PRODUCT AVAILABILITY

Warehouses located in strategic industrial areas enable us to provide you with fast, economical delivery on any Iridite.

4 ECONOMY

The superior performance of Iridite provides low final cost by extending operating life and lowering maintenance costs. In addition, Iridite gives you a finish that adds considerably to the value of your product. There's an Iridite to meet every cost and performance requirement.

5 RESEARCH AND DEVELOPMENT FACILITIES

If you have an unusual application, we will gladly work with you. Our entire staff of experienced engineers and chemists, and our completely equipped facilities are at your service.

IRIDITE—a specialized line of chromate conversion coatings for non-ferrous metals. Apply by dip, brush or spray methods — at room temperature — manually or with automatic equipment. Forms a thin film which becomes an integral part of the metal. Cannot chip, flake or peel. No special equipment, exhaust systems or specially trained personnel required.

If you are using chromate conversion coatings to finish zinc, cadmium, aluminum, magnesium, silver, copper, brass or bronze — consider the above benefits of Iridite. For complete information, contact your Allied Field Engineer. He's listed under "Plating Supplies" in the yellow pages. Or, write for FREE TECHNICAL DATA FILE.

Allied Research Products, Inc. 4004-06 EAST MONUMENT STREET • BALTIMORE 5, MARYLAND
BRANCH PLANT: 400 MIDLAND AVENUE • DETROIT 3, MICHIGAN
West Coast Licensee for Process Chemicals: L. H. Butcher Co. • European Agent: Stora Granberger, Storgatan 10, Stockholm, Sweden

Chemical and Electro chemical Processes, Anodes, Rectifiers, Equipment and Supplies for Metal Finishing

IRIDITE® Chromates | IRILAC® Coatings | ISOBRITE® Brighteners | ARP® Supplies | WAGNER Equipment

Anaconda takes to the road with ideas for greater values and higher productivity

We're in the market with ideas. Ideas for doing new jobs—like making transistor bases and fluid-cooled conductors. Ideas for doing present jobs better—helping you match the metal to the job more precisely so that you can offer equal or greater value *and* reduce total costs.

These ideas are embodied in Anaconda's line of copper, brass, and bronze mill products, the broadest in the industry—and in the vast pool of experience and technical knowledge of Anaconda men.

To put these ideas to work we've taken to the road with a traveling value-analysis clinic, stopping in industrial centers all over the country. We've a truckload of displays representing our principal products to serve as starting points for discussions of the ideas. We're detaching specialists, technical men, mill men, executives to discuss and explain the ideas with all manufacturers who can attend the clinics.

We're also busy generating new ideas in an aggressive research and development program. And we plan to make available soon small, balanced value-analysis teams to go out in the field and work with individual company organizations—make specific suggestions and recommendations regarding materials, fabricating methods, design, etc.

Anaconda is on the move. If you have problems in which you think a new approach might help—call your Anaconda American Brass representative. Or write: Anaconda American Brass Company, Waterbury 20, Conn.

ANACONDA®

COPPER—BRASS—BRONZE
NICKEL SILVER MILL PRODUCTS

Anaconda American Brass Company

Circle 824 on Page 48-B

The Pangborn Vibratory Finishing Machine

THE LONGER YOU OWN IT, THE MORE USEFUL IT IS!

"Every day we find new pieces it can finish," comes the word from the large, Midwestern die-casting firm shown above. And no wonder!

This machine makes itself useful in many ways: cleaning, descaling, radiusing, fine-finishing, burnishing or coloring. It can do all this with metals, alloys, many types of plastic and ceramic parts . . . and at speeds up to 100 times faster than conventional methods. It cleans the intricate or shielded surfaces you can't reach with barrel finishing or other means.

Available in many sizes, the Pangborn Vibratory Finishing Machine is the most compact unit in its field. Its standard equipment includes variable speeds and an exclusive air-cushioned suspension which assures automatic leveling and amplitude control. Auxiliary equipment, media and compounds available for every need.

Send parts with exact finish specifications or finished specimen, for sample processing in our laboratory to: Mr. William E. Brandt, PANGBORN CORPORATION, 1800 Pangborn Blvd., Hagerstown, Md. *Manufacturers of Dust Control, Blast Cleaning and Vibratory Finishing Equipment—Rotoblast® Steel Shot and Grit.©*

Pangborn

OF HAGERSTOWN

Circle 825 on Page 48-B

Polimet

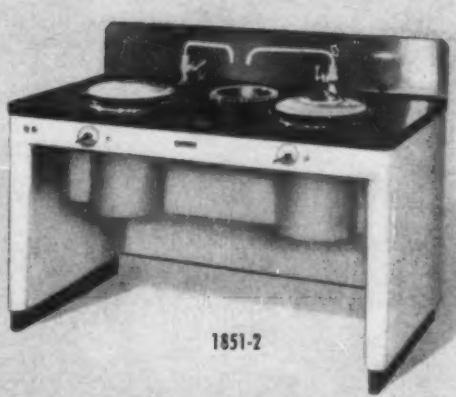
A NEW NAME IN METALLOGRAPHIC POLISHERS

- VARIABLE SPEED—100-1200 r.p.m.
- QUIET OPERATION
- VIBRATION FREE
- EASY CONTROL
- HIGH TORQUE—½ h.p.
- AVAILABLE IN 1, 2 or 3 UNIT TABLES
- INTERCHANGEABLE BALANCED WHEELS
- VITREOUS FINISHED, EASY TO CLEAN BOWL

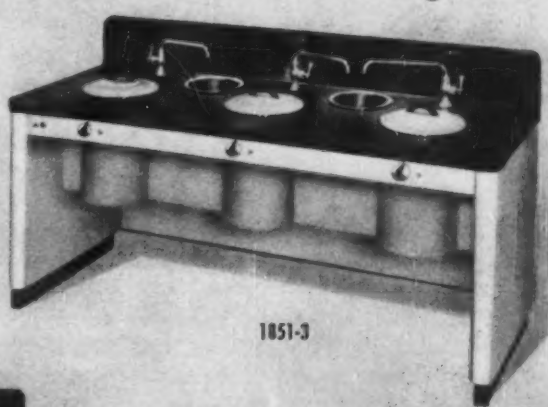
With infinitely variable speed over a wide range it is possible for the operator to select the exact speed desired for the particular sample at hand. The complete speed range is controlled by turning a knob. No cranking is required to change speed, no belts, pulleys or mechanical clutches are used, eliminating the source of most vibration present in other variable speed polishers. The electronic control is accomplished through the use of only one vacuum tube and the complete electronic circuit is mounted on a 4" x 4" panel easily accessible on the outside of the motor.

The 1851 Polimet series is furnished in the Buehler steel polishing tables, finished in silver gray hammertone. The top and edges of the table are black formica. One, two, or three unit tables are available.

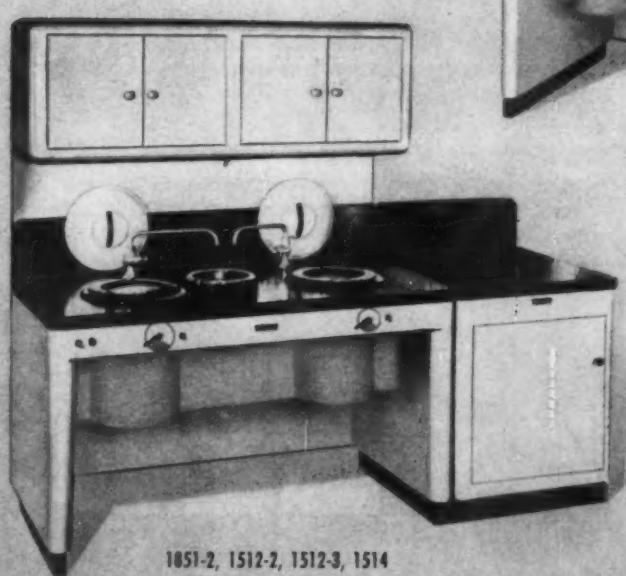
1851-1



1851-2



1851-3



1851-2, 1512-2, 1512-3, 1514

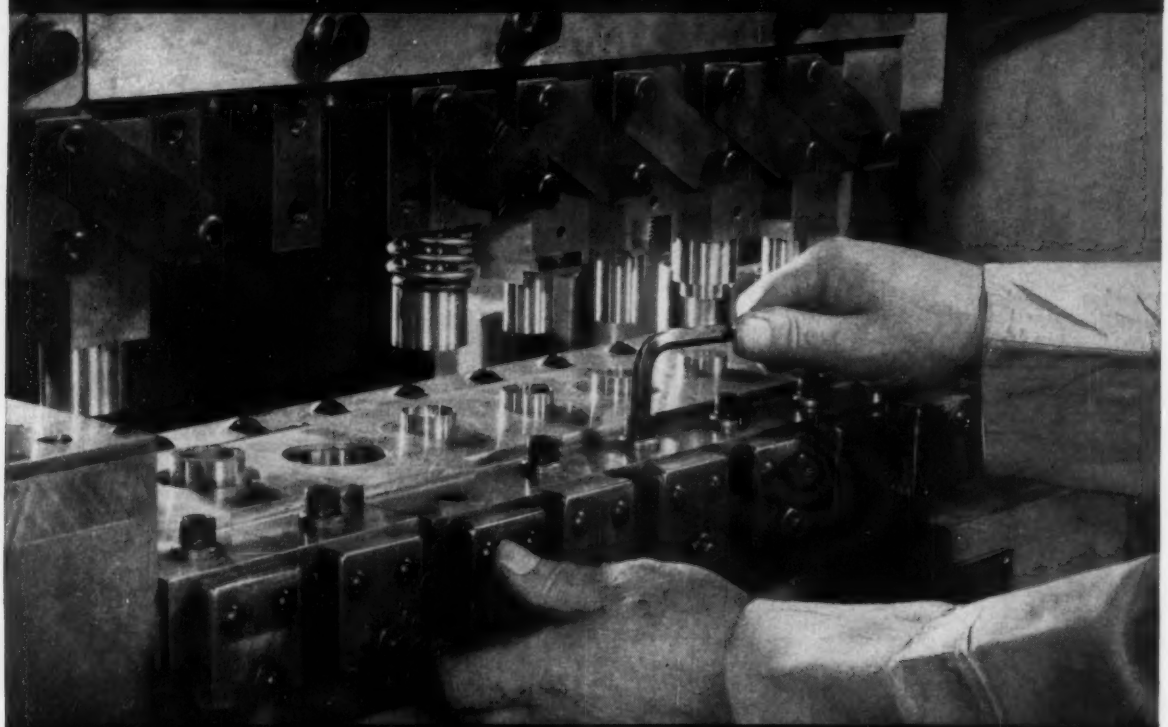
Buehler Ltd.

METALLURGICAL APPARATUS

2120 GREENWOOD ST.,
EVANSTON, ILLINOIS, U.S.A.

Circle 826 on Page 48-B

The most expensive rejections: the ones you don't catch!



Once a part "sneaks through" into expensive and time-consuming forming operations, costs skyrocket. That's why Ansco designs films of maximum readability . . . to catch defects in the initial X-ray inspection.

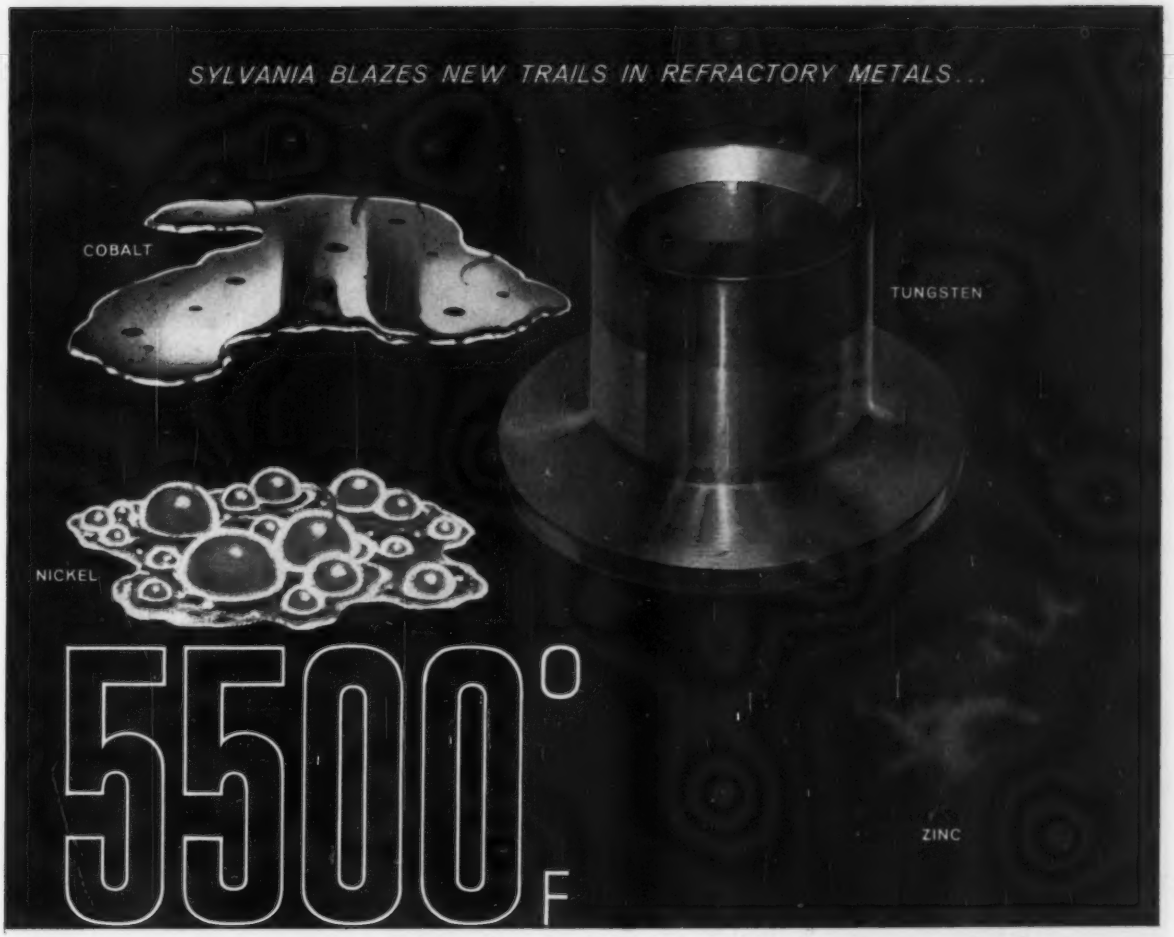
If you are at all concerned about the ones that "sneak through," check Ansco!

Here are four fine Ansco X-ray emulsions to suit your every need: Ansco Superay 'A', fast, high definition film for general purposes. Superay 'B', ultra-fine grain, medium-speed emulsion for maximum detectability. Superay 'C', medium-fine grain and high-speed performance. Superay 'D', designed to provide extremely high speed when used with calcium tungstate screens. Ansco, Binghamton, N. Y., A Division of General Aniline & Film Corporation.

Ansco

Industrial X-ray

Circle 827 on Page 48-B



REMARKABLE NEW PROCESS

...opens way for you to solve critical high-temperature design problems

At 5500°F. cobalt runs like water. Nickel boils. Zinc vaporizes. But tungsten remains solid.

To make this property pay off for you, Sylvania recently put to work its new isostatic pressing and sintering operation. Through this operation, it can produce tungsten or molybdenum ingots up to 10" in diameter and up to 4 feet long. *Sylvania now produces all four*—billets and ingots for forging, electrodes for arc casting, blanks for machining, or machined blanks ready for your use.

Perhaps you've never considered refractory metals as the answer to your needs. But the same properties that solve the problems of throat inserts for rockets and missiles can pay you dividends in piercing points, boring bars, dies, tools and in countless other ways.

Want more facts? Or experienced technical help in proving out your special ideas? Just write Chemical & Metallurgical Division, Sylvania Electric Products Inc., Towanda, Pennsylvania.

SYLVANIA

Subsidiary of GENERAL TELEPHONE & ELECTRONICS

Circle 828 on Page 48-B

Stove pads place easier with heat-resistant concrete

Heat-resistant concrete in foundation pads is just one use of concrete made with LUMNITE calcium-aluminate cement and aggregates in blast furnace stoves. Because it resists heat and abrasion, concrete made with LUMNITE cement can also be used to line sections connecting to hot-blast mains as well as flues, doors and stacks. In addition, it can be used as dome and wall insulation. And precast shapes can be formed, for doors and manholes. Installation is fast, easy, economical—by guniting, pouring or plastering. Concrete reaches full strength in 24 hours.

Write for detailed information on aggregates, proportions and methods of making concrete with LUMNITE cement: Universal Atlas Cement, 100 Park Avenue, New York 17, N. Y.

L-208

"USS," "Atlas" and "Lumnite" are registered trademarks

Universal Atlas Cement
Division of
United States Steel

Offices: Albany · Birmingham · Boston · Chicago · Dayton · Kansas City · Milwaukee · Minneapolis · New York · Philadelphia · Pittsburgh · St. Louis · Waco

Circle 829 on Page 48-8

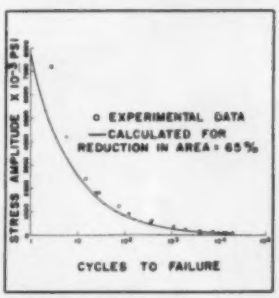
$$S = \frac{Ec}{2\sqrt{N}} + Se$$

A NEWLY DERIVED FORMULA FOR PREDICTING MATERIAL PROPERTIES . . . . . IN ADVANCE

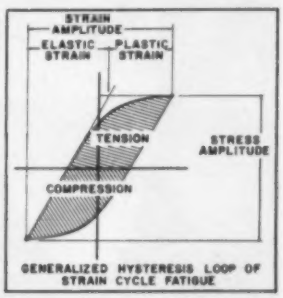
Instron is proud to have played a part in the development of a workable equation for predicting the low-cycle fatigue resistance of metals (and other materials). Low cycle fatigue deals with mechanical and thermal cyclic strain in materials from ¼ cycle up to approximately 10^5 cycles. Recent investigations have shown the tremendous importance of establishing reliable design criteria in this critical plastic strain range.

No — we can't take credit for the equation itself (which you can study at your leisure below.)* But we are responsible for the Instron Universal Tester, equipped with reverse stress cycling controls, which helped to prove that the equation was workable. Data obtained from low-cycle strain fatigue tests on 12 different materials, conducted on the Instron, corroborated the equation.

Which is yet another instance of what we mean when we say "you can do more with an Instron". If you have any problem at all related to materials testing, you should (at the very least) have the complete Instron catalogue. Also available: our ever-growing library of articles on advanced testing techniques, covering many fields. Yours for the asking — just mention your particular field of interest.



Typical curve (for 1018 carbon) shows correlation between Instron data (dots) and formula (solid lines).



Generalized hysteresis loop of strain cycle fatigue.

Accuracy of cycling data provided by Instron Universal Tester furnished a reliable standard against which to check new formula.

* $S = \frac{Ec}{2\sqrt{N}} + Se$ — New formula for stress amplitude of a material is based on just 3 knowns, all easily arrived at by conventional test methods: 1) E, modulus of elasticity; 2) c, a constant easily related to the per cent reduction in area and 3) S_e, the endurance limit or yield stress point. N represents cycles to failure. Satisfactory correlation with experiments up to 10^5 cycles to failure was found. For more insight into this fascinating development, drop us a line.

For advanced stress analysis equipment look to

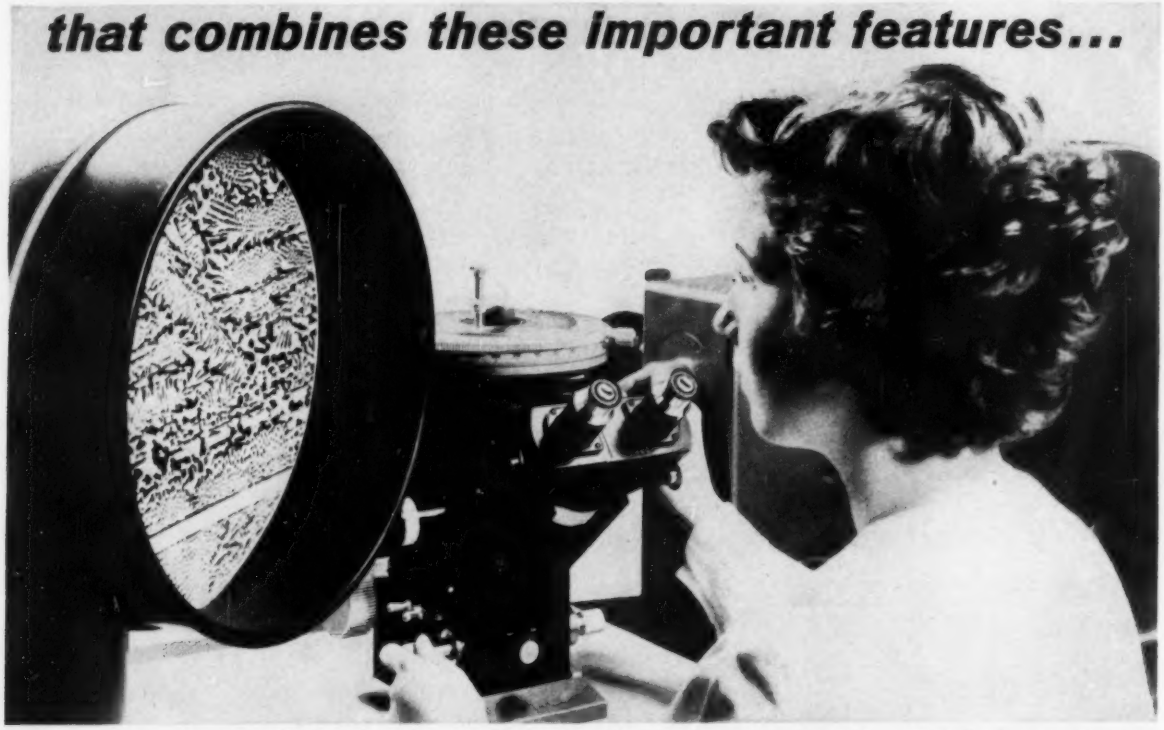
The Instron comes in various models and sizes to suit the widest applications for tests under all kinds of environmental conditions Shown: Floor Model — load ranges from 2 grams to 10,000 lbs

INSTRON

2507 Washington Street, Canton, Mass.

Circle 830 on Page 48-B

ONLY LEITZ *offers you the Micro-Metallograph that combines these important features...*



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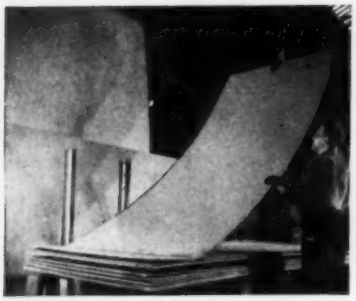
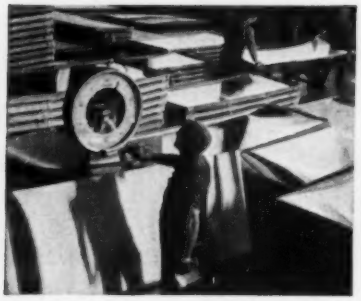
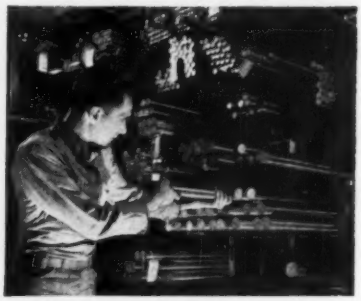
BUYERS' GUIDE . . .
to Ryerson service on stainless



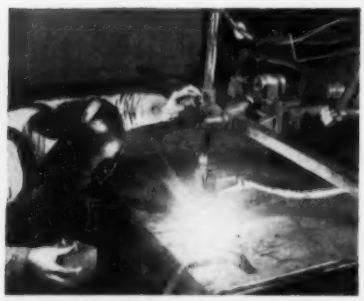
PLATES—Available in 9 analyses including plates to Atomic Energy Commission requirements and to ASTM specifications for code work. Also low carbon types for easy welding.



SHEETS—11 analyses of Allegheny stainless sheets in stock including nickel and straight chrome types. Also extra wide sheets to reduce welding costs, expanded and perforated sheets.



BARS AND ANGLES—Rounds, squares, flat's, hex's and angles in 8 types including free-machining bars with both analysis and mechanical properties controlled.



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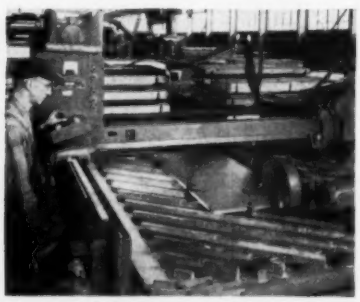
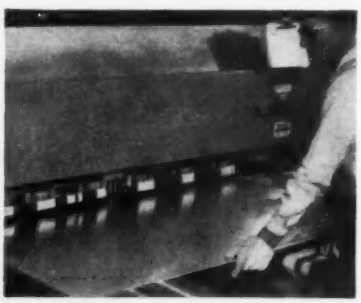
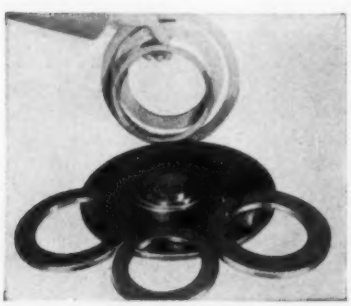


TRUE-SQUARE ABRASIVE CUTS. —Stainless plates to 12′ x 25′ cut true square on abrasive disc machine. Length and width tolerance plus or minus 1/32″.



SHEARING—Accurate cutting of stainless sheets and light plate to the industry's tightest specifications. Shear hold-down clamps padded to protect sheet finish and flatness.



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Metal Progress

Vol. 79, No. 2 February 1961

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New Potentiometers Use Strain-Gage Principle

Changes in resistance of a wire as it is stretched or relaxed, a characteristic already used in strain gages, is now being employed in potentiometers. A new balancing circuit which is based on such a response has been introduced by Brown Instruments Div., Minneapolis-Honeywell Regulator Co., in Philadelphia in its recently announced series of industrial potentiometers called ElectroniK 17. In the instruments four stressed wires substitute for the usual slide-wire arrangement.

If you are concerned with temperature measurement, you probably recall that a potentiometer is basically a precision millivoltmeter which measures the emf. generated by a thermocouple. The unknown voltage from the thermocouple is balanced against an opposite voltage of known magnitude by moving a slide wire across a voltage divider. Movement of the slide wire contact is shown on a scale, usually calibrated to indicate temperature.

Most industrial potentiometers today are self-balancing (the thermocouple emf. is amplified to drive a reversing motor which in turn moves the slide-wire contact). Resolution – the ability to detect small changes in the emf. of the thermocouple – is limited, however, by the number of turns of wire on the voltage divider. In addition, precision of such instruments suffers because the slide-wire contact tends to bounce across the turns on the divider when it travels rapidly. Mechanical wear of the contact and the wire has been another problem.

To eliminate these shortcomings, engineers at Brown Instruments have devised a balancing element called a "Stranducer" (see photo) in which four prestressed wires of equal resistance are fastened to a pivot arm. When the signal from the thermocouple changes, it drives a balancing motor which moves the pen or pointer along the temperature scale and turns the pivot arm of the Stranducer. As the arm rotates, it increases tension on two of the wires and relaxes it on the others. The change in stress in the wires is accompanied by changes in their electrical resistance and, because they are connected as a Wheatstone

ELECTROMECHANICAL STRAIN GAGE
It Is Used in the Balancing Circuit of New Potentiometers

bridge, the circuit is rebalanced, thus nullifying the current which is driving the balancing motor.

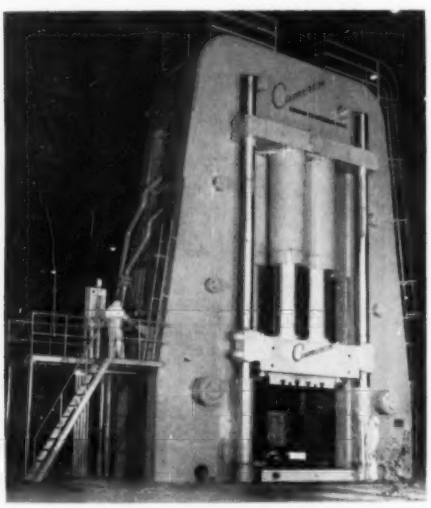
In addition to the strain-gage type of balancing circuit, the new potentiometers also incorporate other improvements. They will filter out stray signals which may be induced in the lead-in wires and instrument, or picked up when the thermocouple is attached to a source of d-c. or a-c. voltage. Also, a common cold-junction compensator will accommodate all types of thermocouples. Power is supplied to the measuring circuit by a Zener diode network instead of a dry cell. This maintains a constant current despite fluctuations in line voltage and ambient temperature. It also eliminates the need for periodic standardization.

All these features add up to a major improvement in potentiometer circuitry which not only results in high accuracy (0.25% of the total voltage across the Stranducer) but also in lower cost than the widely used ElectroniK 15 series.

Big Forging Press Shapes Tough Alloys

A new 20,000-ton press (see photo) is ready to forge steel and refractory metals into turbine cases, shafts, landing gears and parts for atomic power plants, missiles and jet engines. Designed and built at the Cameron Iron Works, Inc., Houston, Tex., in less than six months, it is the largest privately owned closed-die forging press in the free world. Standing 50 ft. high and measuring 31 ft. from side to side, the press combines main rams which supply a total force of 20,000 lb., a piercing ram (4200 tons), side rams (5000 tons each), four pushback rams (940 tons) and a 650-ton knockout punch.

First forging made was an aircraft shaft of A-286 weighing 6000 lb. The funnel-shaped part measured 12½ ft. long. Diameter at the large end was about 3 ft.; at the shaft end the diameter was 12 in. An 8-in. hole was pierced axially through the shaft.



NEW 20,000-TON FORGING PRESS
Forgings and Extrusions Weighing Up to 30,000 Lb. Can Be Produced

Forgings weighing up to 30,000 lb. can be made. In addition, extrusions can be produced after dropping the main piercing ram out of the press. This leaves a hole in the main bolsters, moving and top platens and permits shapes up to 30 ft. long and 56 in. in diameter (but weighing no more than 30,000 lb.) to be extruded vertically through the press.

Auxiliary equipment includes a 4000-ton press for preliminary blocking and forming and a 6000-ton press for final shaping and piercing.

Outlook for Ferroalloys in 1961

One of the hopeful areas for ferroalloys is in stainless steel production which is expected to maintain its 2-to-1 growth ratio over the steel industry as a whole. According to William H. Feathers, president of Union Carbide Metals Co., Div. of Union Carbide Corp., the output of stainless in 1961 may increase by as much as 10% to about 1,100,000 ingot tons.

Aluminum Continues Uptrend in Auto Industry

Use of aluminum in automobiles now averages 62.8 lb. per car in the 1961 models. If the upward trend continues, the average auto will require at least 115 lb. of the light metal by 1965, according to Robert B. McKee, vice-president in charge of sales for Aluminum Co. of America. Speaking in Detroit recently, he also predicted that the next five years will see aluminum bumpers, radiators, wheels and rear axle housings on autos.

In bumpers, Alcoa feels there is an annual potential for 150 million pounds of aluminum. These may be either stamped or extruded using such alloys as 6563, a heat treatable grade which is first cold formed in the T4 condition, then aged and anodized.

Radiators will also account for a good deal of aluminum in autos – perhaps 80 to 90 million pounds a year. A good example: All those now being installed in 1961 Corvettes are aluminum. The radiator, which combines a water and oil cooler in one unit, is dip brazed.

Aluminum is already well established in transmission housings. Some 100 million pounds will be required in this application in 1961 models, an increase of 25% over last year. It is also expected that rear axle housings of aluminum will make their appearance within the next two years – it is estimated that 10 to 15 million pounds annually will be needed by 1965.

An annual survey, the sixth made by Alcoa, shows that the Oldsmobile F-85 with its aluminum

engine carries 159 lb. of the light metal, the largest amount of any of the current models. Aluminum in General Motors cars has increased 32% over last year bringing the average to 67 lb. Chrysler Corp. leads the automobile industry with a 76-lb. average.

The total amount of aluminum going to automobiles should show a slight increase over 1960, although estimates place production for the year at about 5.3 million cars. This compares with 1960's output of 6 million autos.

Shear Forming Reduces Costs of Rocket Cases

Large horizontal shear forming machines will soon be used in the production of rocket motor cases for the Minuteman ICBM. To be used at Allison Div., General Motors Corp., the machines will form sections of the rocket case starting with three cylindrical forgings of ultra-high-strength steel. The sections are then welded together. In present practice four ring forgings are machined to size and welded to fabricate a case.

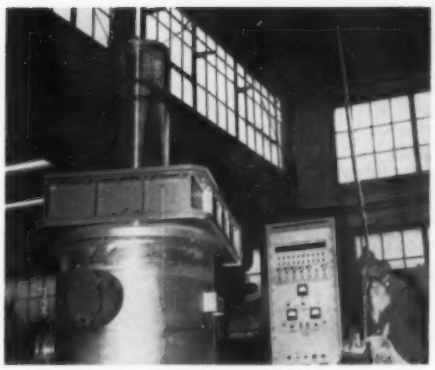
Built by Lodge & Shipley Co. of Cincinnati, Ohio, the machines are equipped with two rollers rather than a single one, an arrangement which gives greater rigidity and higher feed rates. Because the rollers can be offset from each other, one can be used to preform the metal and the second for finish forming. Single-pass reductions of 50% are possible starting with a ¾-in. thick blank of mild steel or a ⅝-in. blank of stainless. Cylinders up to 70 in. in diameter and 84 in. long can be produced. Either flat or preformed blanks can be employed.

In changing from machining to shear forming, Allison will save on material and fabricating costs. Fewer and shorter ring forgings are required. As a result the cost of the starting material will be reduced by 50%. An 80% decrease in machining costs is also expected and one girth weld will be eliminated because only three shear-formed sections instead of four machined rings are needed to complete the full length of the case.

Larger Vacuum Furnaces Go Into Operation

Vacuum furnaces are getting bigger. A sign of the trend is a recent installation at Convair (Astronautics) Div. of General Dynamics Corp. in San Diego, Calif. Here a vacuum furnace with an interior chamber measuring 6 ft. in diameter and 10 ft. long went into operation for heat treating metals for the Atlas ICBM and the Atlas-Centaur space vehicle. Built by F. J. Stokes Corp. of Philadelphia, the new furnace draws power from a 1000-kw. substation generator – enough electricity for a town of 10,000.

Electron beam melting has also taken a forward step with the introduction of a furnace (see photo) which can produce ingots from 12 to 20 in. in diameter and 6 ft. long. With this large furnace,



ELECTRON BEAM FURNACE
Big Ingots Are Now Being Cast

which was built by Temescal Metallurgical Corp., Richmond, Calif., it is economically feasible to melt and cast superalloys by the electron beam technique.

Dealing With Corrosion in Automobiles

Corrosion in automobiles is not only accelerated by increased use of salt for snow and ice removal, but also aggravated by the more complex structures in unit-body-frame construction. Box sections and other restricted configurations are difficult to paint but are good traps for corrosives. They impede ventilation and cause slow drying, a condition which favors corrosion.

Speaking at the recent S.A.E. International Congress and Exposition in Detroit, R. B. Mears, vice-president of applied research, United States Steel Corp., pointed out that high-strength low-alloy steels could help solve the problem. In addition to greater strength, this type of steel exhibits better corrosion resistance than carbon steels. It takes on a tightly adherent rust film in contrast to the voluminous corrosion product on carbon steel.

Deterioration of an auto body or structural member can be slowed by using galvanized steel. Box sections, for example, can be shaped from steel coated on both sides so that the thick, more protective layer is on the interior of the section where it is needed most. Zinc-rich paints on underbody parts, adequate phosphate coatings, sealers and good design all contribute to longer auto life.

Diffusion Bonding Joins Copper and Its Alloys

Test results on diffusion bonds between copper parts and certain of its alloys reveal that they are superior in tensile, shear and fatigue strength to soft-soldered joints. The new process, worked out at Chase Brass & Copper Co. (a subsidiary of

Kennecott Copper Corp.) in Waterbury, Conn., also results in a joint which retains the high electrical and thermal conductivity of the copper.

In the process a special coating is applied to copper strip already rolled to finish gage or to fabricated parts which must be joined. The bond is made by heating the parts, held in close contact with each other, at 1700 to 1800° F. for 5 to 15 min. in hydrogen or inert atmosphere. Strip which is coated can be formed by many of the usual methods such as blanking, deep drawing, bending and stamping. Joining can also be done by placing a copper strip that is coated on both sides between any two components of uncoated copper.

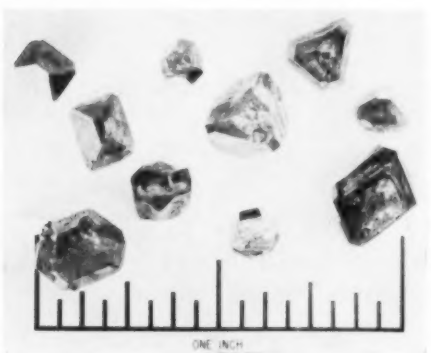
At the present time the bonding process is limited to alloys of high copper content. True diffusion bonds are not achieved with brass containing more than 5% zinc. Instead a braze type of joint is made which is satisfactory until zinc content reaches 30%. Another possible limitation is that the base metal is annealed when heated to the required diffusion temperature. In some instances subsequent mechanical working may be performed to strengthen the base metal. This, of course, is not a problem in applications where the need is for physical rather than mechanical properties.

Particular uses for the bonding technique are where vacuum-tight joints that do not contain constituents of high vapor pressure are required. The process will also prove useful in constructing electrical equipment (motors, generators, transformers) and heat exchangers.

Progress in Nonmetallic Materials

Man-made diamonds the size of fine grains of sand but large enough for many polishing, grinding and cutting operations have been used in industry since 1957, and it looks as though larger stones perhaps as big as a carat will make their appearance soon. Continuation of the work on man-made diamonds at General Electric's Research Laboratory in Schenectady, N.Y., has resulted in stones up to 1/10 carat in size which are of excellent industrial quality. Diamonds of this size, needed for metal-bonded diamond wheels and saws, are not yet commercially available.

Stones of more than 1 carat (see photo) have also been made. These are dark in color and, because of structural imperfections, they are not strong enough for industrial use. Just when G.E. scientists will be able to obtain adequate strength in the big diamonds can not be predicted. When achieved, it will put the large stones on a competitive basis with natural diamonds (most come from the Congo) for drills, dressing tools, dies and single-point cutting tools.



LARGE MAN-MADE DIAMONDS
Carat-Size Stones, Though Imperfect, Have Been Made in the Laboratory

Another interesting example of progress in nonmetallics is the use of thermoplastics for instrument cluster housings in automobiles. Dow Chemical Co., Midland, Mich., has revealed that a heat and impact resistant polystyrene (Stryon 440) is being made into instrument cluster retaining plates for the 1961 Buick. The plastic part replaces a zinc die casting and may result in savings of 45¢ per automobile.

From Here and There

Despite the inroads being made by aluminum and plastics in automobiles, zinc continues to increase in use, according to John L. Kimberley, executive vice-president of the American Zinc Institute, Inc. Average amount of zinc used per car in 1959 was 60.5 lb. In 1960 the amount rose to 69.4 lb. (compacts included) and in 1961 each full-size car carries an average of 75 lb. of zinc.

• • • •

Experience at National Forge Co., Irvine, Pa., indicates that its new Dortmund-Hörder vacuum degassing unit will be able to treat all of the steel the company makes. The unit can degas eight 10 to 60-ton heats in a 24-hr. period.

• • • •

A new bright-annealing line for stainless steel is now in operation at Roemer Works of Sharon Steel Corp. in Farrell, Pa. Of major interest to automobile makers and parts fabricators who use large quantities of 300 and 400 series of stainless, the line will produce bright-annealed strip 23 15/16 in. wide and 0.010 to 0.100 in. thick. Annealing is done in hydrogen or disassociated ammonia.

Metals and Fabricating Methods for the B-70

Now that the B-70 program is beginning to steady on its course, it seems timely to look at some of the details of metals selection and fabrication which engineers will use in building the Mach-3 aircraft. These will be revealed for the first time in *Metal Progress* next month in a special issue devoted to the theme "Producing for the New Technologies". Articles will describe how engineers in and close to the aerospace industry are dealing with the many materials problems encountered in such vital programs as Dyna-Soar, Titan, Bomarc and Polaris.

Critical Points

By the EDITORS

Testing: The Best Quality Insurance Known

You will remember that years ago mass-produced items such as gears and piston pins were merely "spot checked". A dozen or so gears (or pins) would be taken from a large batch and checked for dimensional accuracy, hardness, and other pertinent properties. There was no good way to be sure that all of the other parts in that particular batch were the same – it had to be taken for granted.

This system worked fairly well as long as consumers were reasonably undemanding, but recent years have seen an increasing desire to reach and maintain quality at levels never considered in the past. To point this up, Edward G. Budd, Jr., president, Budd Co., stated (at the Awards Luncheon held during the A.S.M. Metal Congress and Exposition in Philadelphia) that, "Our quality levels have risen along with the technical advances, but our problems now arise from the fact that even the new levels are not adequate for the growing complication of some products. The demand for levels of quality is almost unbelievable in some cases. There are some 300,000 parts in a long range missile. It has been estimated that even if 99.99% of integrity in the component parts is maintained, only three missiles in 100 will function properly."

Of course, a defect in an electric toaster or a television set will not produce the spectacular results that it will in a missile, but the unfortunate owner of the defective item will complain just as loudly. As a consequence, industry is making decided efforts to get more consistent quality from part to part.

"I think we have learned a fundamental truth", Mr. Budd continued in his talk. "It is cheaper in the long run to build a good product than a poor one, however simple or complicated the product may be."

Now, it is a patent fact that the one sure way to assure good quality in all of the items in any batch – be it gears, piston pins, missiles, toasters, or television sets – is to test every one of them. Since this must be done without destroying the part, the only answer is some form of nondestructive test. As a result, there is a wide and growing interest in such methods as magnetic particle tests, eddy current tests, radiography, and the like.

To answer this continually increasing demand for more information, *Metal Progress* will publish, in the coming months, a series of articles concerning nondestructive testing. This eight-part series, which begins with the article "Why Nondestructive Testing Is Needed" on p. 70, was taken from a symposium held at one of the plants of Westinghouse Electric Co., a noted and proficient user of all forms of such tests. We hope that those of you who are troubled with quality control problems (and who isn't these competitive days?) will find much of interest in this series of comprehensive articles.

Why Nondestructive Testing Is Needed

*By ROBERT C. McMASTER**

The constant increase in competition coupled with the growing demand for quality has caused manufacturing industries to concentrate on nondestructive testing as a means for reducing waste and improving reliability. A number of the general aspects, including both production and economic standpoints, to be considered in applying such testing are discussed in the article. (S13)

NONDESTRUCTIVE TESTING is a basic tool of industry. As a powerful weapon for reducing costs, improving product quality, and maintaining quality levels, it can play an important role in improving the competitive position of the manufacturer. In fact, managers who early recognized its potential, gained considerably through the intelligent use of nondestructive tests. Today, their companies employ such tests as a basic means of implementing management policies.

On the other hand, failure to use nondestructive tests effectively can be disastrous in corporate management, particularly in industries whose products are judged by their safety features. Experiences in the airframe industry clearly illustrate this. Twenty years ago, some airframe manufacturers, in efforts to better product reliability, pioneered the development and application of new nondestructive tests. Others lagged behind in this effort, considering such tests as an added expense to be avoided as long as possible. Today, those who neglected nondestructive testing are no longer in the airframe business. Still others limited their use of nondestructive tests to military air vehicles where such tests were required by military specifications. These manufacturers are no longer in the civilian airframe market.

*Professor of Welding Engineering, Ohio State University, Columbus; Editor, Nondestructive Testing Handbook.

A Profit Is Essential

However, the threat of corporate failure is not the prime reason why management should

use nondestructive tests. Today, and in the future, a basic responsibility of management is to operate at a profit. Under competitive conditions, profits can be assured only by an effective program leading to reduced material and production costs, elimination of wasted labor and machine time, assurance of adequate product quality that eliminates final rejections, and the improvement of existing products and development of new products that receive wide customer preference. Nondestructive tests can play an effective part in such a program.

A vital responsibility of management is to study all appropriate factors (see the box on p. 75) and to evaluate them on a dollar-and-cents basis for specific areas within the corporation. Furthermore, insofar as is feasible, all factors of costs and benefits should be evaluated, including the incidental advantages of sales and advertising costs, and promotional and competitive advantages accrued or lost by management decisions in this area.

Generally, casual or occasional observations alone are not enough to estimate the costs of quality control. All factors must be carefully analyzed. If there is a possibility that hidden production costs are being wasted on improper or unnecessary nondestructive tests, management consideration is indicated. As an example, if a costly nondestructive test (such as film radiography) is being used where a much cheaper test (such as fluoroscopy) could be employed with equal reliability, the latter should be used.

Individual items used in nondestructive testing vary in cost from less than $100 for simple liquid-penetrant test kits used in shop or field inspection to investments of perhaps ten to fifty thousand dollars for X-ray test facilities. Very expensive test systems, such as multimillion volt X-ray equipment, television fluoroscopy, or ultrasonic immersion test units with automatic bridge scanning, can range in price from perhaps $50,000 to $300,000 or more. Despite these costs, such systems find practical application in industry.

Making Test Personnel Effective

A few words about personnel are in order here. Key test personnel have responsibilities comparable to those of higher management in that their decisions can be equally important to the manufacturer. Consequently, such personnel should have considerable freedom within the plant and be encouraged to keep abreast of all new developments. It must be emphasized that free interchange of technical information on a personal basis has been the characteristic of this field.

When key personnel are denied information by management restrictions, they are partially crippled in terms of their potential value to the corporation. Needless security or commercial restrictions can be a very short-sighted management policy leading to excessive test costs, duplication of developments, and repetition of errors. And in the end, the conservative company will be far behind its competitors in the field of nondestructive testing. There is probably no cheaper or more effective means of training key personnel than active participation in technical society committee activities and extensive personal contacts throughout industry.

Reduction of Materials Costs

In using nondestructive tests to lower costs, one of the first points of attack is at the level of raw materials control and coordination with design. To start with, designers, materials engineers, and nondestructive test engineers can study possible areas in which materials savings could be made if the quality of the raw material were controlled adequately at a reasonable cost. Then, the designer can use less material in each component. As an extra benefit, such

Nondestructive Testing for Management

"Why Nondestructive Testing Is Needed" is the first of a series of articles which is planned to tell technical management how to use modern methods for nondestructive testing more effectively in production operations. Based on a week-long program of special talks given to engineers at Westinghouse Electric Corp. (at a company-wide "Nondestructive Testing Seminar"), future articles in the series will include:

- When to Use Ultrasonic Testing
- What to Look For in Ultrasonic Testing Equipment
- Where to Use Radiography
- Eddy Current Testing
- How to Use Magnetic Particle Methods
- How to Use Penetrant Testing Methods
- Special Test Methods for Special Problems

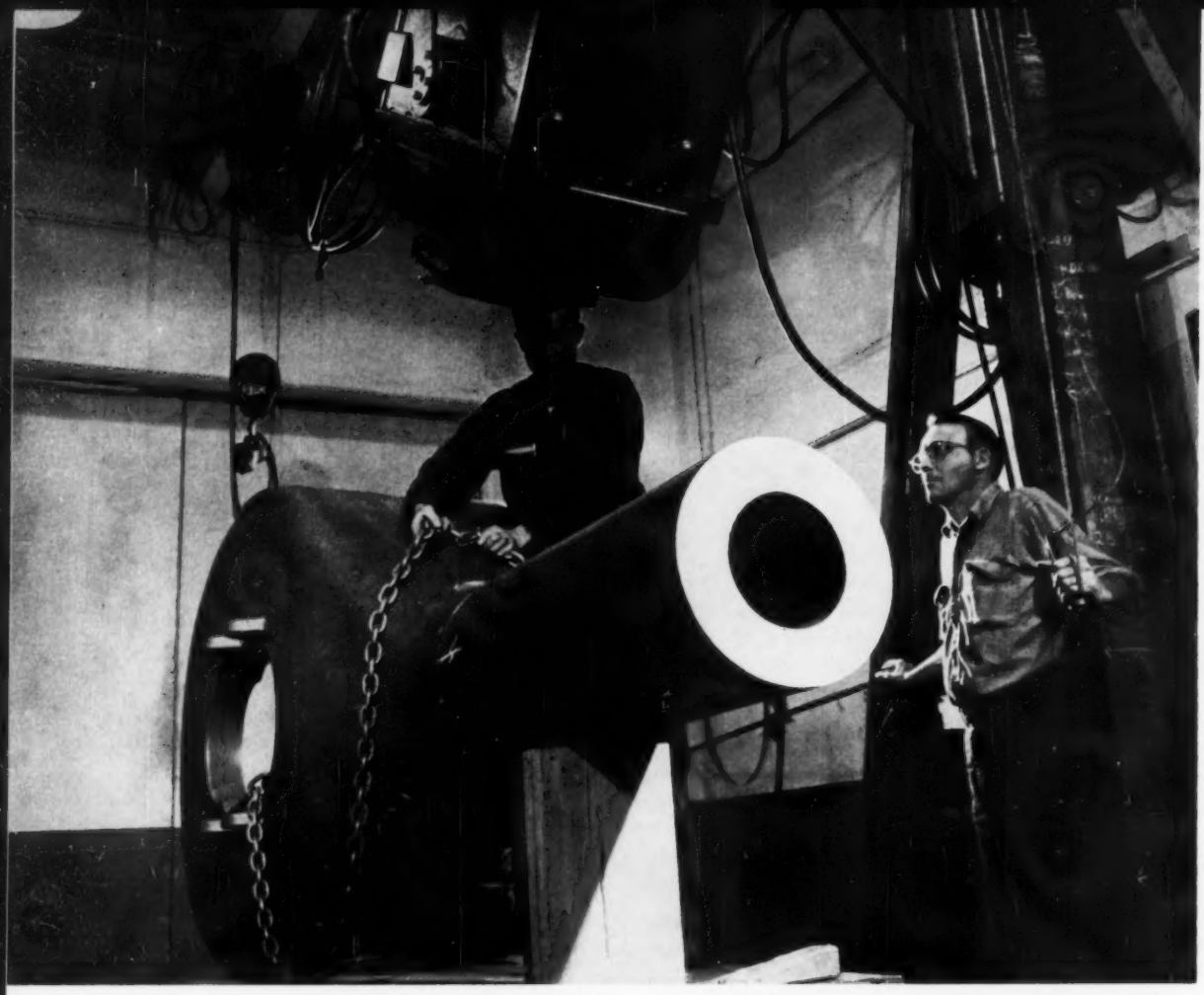


Fig. 1 – Casting Is X-Rayed (Electro-Alloys Div., American Brake Shoe Co.) to Determine Internal Soundness

reductions can often be coupled to a design improved through stress analysis.

The airframe industry has long employed nondestructive tests to eliminate incoming defective materials from the production line. Obviously, both machine and labor time can be saved if imperfect materials are rejected before any time or effort has been spent on production. By expending all labor only upon good material, over-all productivity can be improved.

Monitoring the Production Line

If raw materials are carefully controlled, the next point of attack in applying nondestructive tests comes in processing. After each basic operation which is critical to the service performance of the final product, the part is tested. In a nutshell, the optimum point at which to check for processing defects is directly after the process in which they originate.

For example, after heat treating, parts can be checked for hardness, tensile strength, ductility, grain size, cracks, decarburization, and many other factors which might be affected by the treatment. In some instances, such tests can be made automatic to provide feedback controls for the process (if continuous) as well as statistical quality control charts for later evaluation by management.

As another example, checks of machined parts (directly after machining) can reveal dimensional error or inadequate surface finish. Then, if the process is tending to go out of control, it can be immediately corrected. Rapid nondestructive tests can also weed out welding defects, and poor welding procedures can be adjusted. In addition, if the part is tested immediately after the defect is initiated, defective materials can be scrapped. This eliminates further costly processing.

As a further advantage of on-the-spot testing, immediate feedback of information from in-

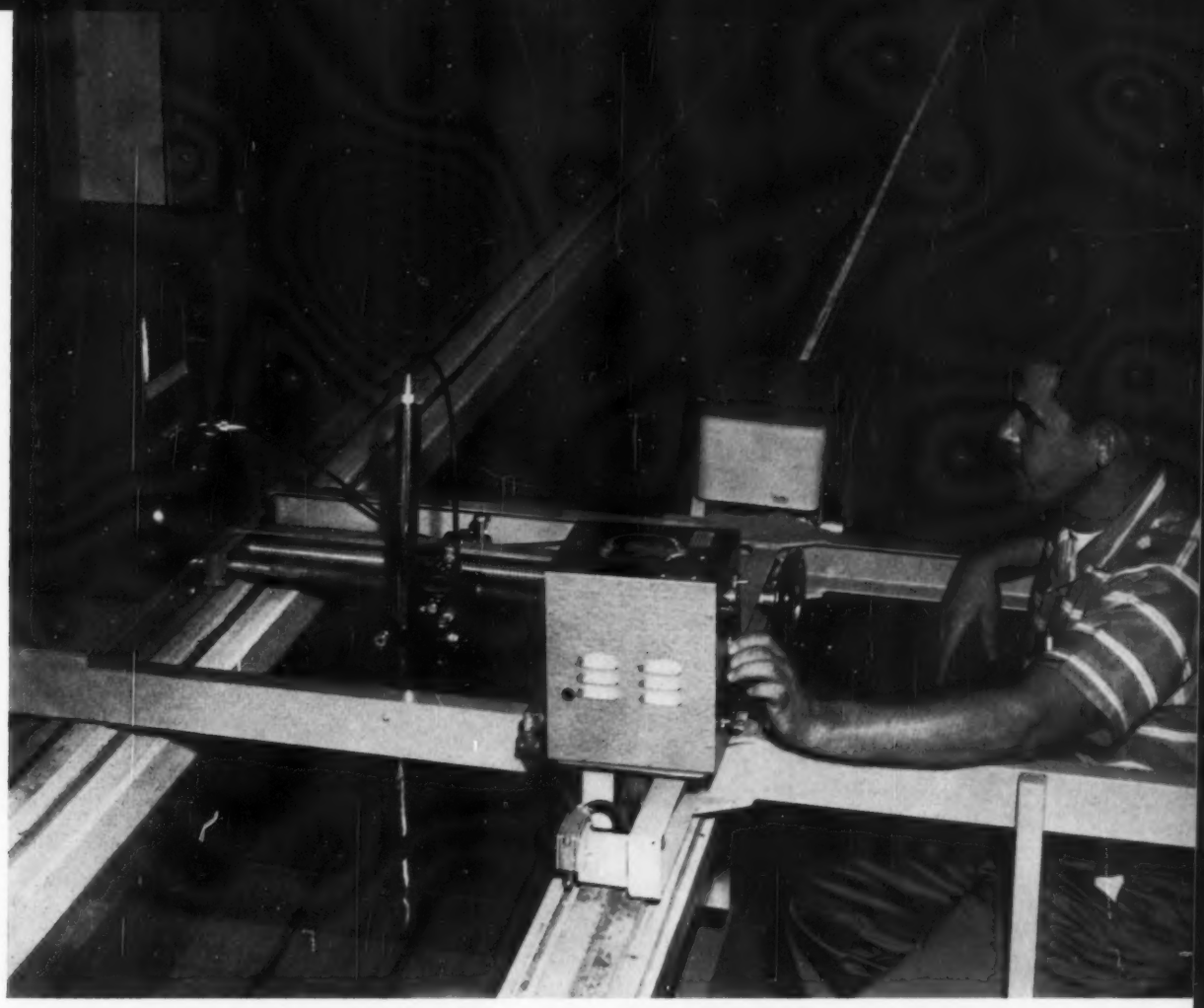


Fig. 2 – Installation at Douglas Aircraft for Testing Honeycomb Panels Ultrasonically

spection often leads to detection of the causes for the defects while the causative condition is still apparent. This can lead to prompt improvement in process or control, eliminating many defectives from future production. (Changes in product design also can help.) By indicating process changes that insure product quality, many nondestructive tests often work themselves out of a job. This seeming contradiction can usually be considered as the ultimate measure of success of a given test.

Improvement in Process Control

Nondestructive test devices can serve as basic components of feedback process control systems since all such tests are based upon measurements which do not damage the materials or parts being inspected. In several instances, such indirect measurements have become more accurate and reproducible than the direct measurements they have replaced. For example, one facility has reported that ultrasonic thickness testing (of nuclear fuel elements) from one side only proved more precise and reproducible than the most careful micrometer measurements by carefully trained personnel.

It has been reported that eddy current tests monitor the entire output of ball-bearing factories in Germany. In a matter of milliseconds per measurement, balls are thoroughly tested as they roll through four test coils. In one coil, the ball diameter is measured to the order of one micron, the balls being separated into 13 classes by diameters. The next coil rates eccentricity down to one micron on groups of balls with similar diameters. Hardness is measured more precisely than by Rockwell "C" hardness testers as balls pass through the third coil. For the last step in this particular setup, balls containing defects are detected and segregated as they pass through another coil.

For each such measurement, statistical qual-

Fig. 3 – Discaloy Forging for Gas Turbine Being Ultrasonically Tested for Soundness at Westinghouse Electric Corp.

ity control records are obtained automatically in the form of frequency distributions. These can show the presence of two or more populations, or indicate deviation trends that can lead to defective production if not corrected. Also, feedback controls can be actuated by the statistical trends the automatic equipment reveals.

In the United States, isotope radiation-gaging systems have been developed which measure metallic sheet thicknesses while the material passes through rolling mills at high speeds. Such systems sense deviations from desired gage, and change screw-downs on rolls rapidly enough to result in increased percentages of within-tolerance product. Many other examples could be cited where nondestructive measurements provide greater accuracy and speed than sampling tests involving direct measurement or destructive evaluations.

Improvement in Equipment Maintenance

Modern production equipment is often an integral part of a continuous production line. Here, equipment failures can cost far more, in lost production time, than the cost of repair of the specific machine that has failed.

Nondestructive test systems can monitor equipment either by directly measuring the deterioration of critical components, or by continuous automatic testing of machine parts in action. They can also oversee machine deterioration and warn of impending failure by measuring tell-tale properties of the machine's products. Any spread in dimensions or properties of output parts, or trends toward one tolerance limit, can indicate that the machine is about to go out of control. With advance warning, the machine can be shut down before costly failure can occur, or corrective action can be taken during the next maintenance period.

Monitoring the Labor Force

Since the cost of skilled labor is a major factor in many types of production and assembly processes, control of quality requires constant indoctrination of personnel and supervision of output. An example is in the welding of pipelines. Welds are X-rayed primarily to control

The Benefits of Nondestructive Tests

- Reduction in the quantities and initial costs of raw materials required for production.
- Elimination of further labor and machine costs on materials or parts which contain hidden defects. Otherwise, rejection would come later when the defects appear.
- Reduction in the quantity of materials used through redesign based upon assured material quality. Designers do not need the material normally allowed to compensate for the possibility of inferior material properties or the presence of defects.
- Reduction in lost machine and production time resulting from operational failures and shutdown of plant equipment. Nondestructive tests can reveal trends toward defects which could otherwise, if undetected, cause trouble.
- Reduction in assembly and rework time caused by failure of operations to produce the desired properties and dimensions in components or subassemblies.
- Increased productivity resulting from full use of facilities for acceptable final products.

the performance of skilled pipeline welders, rather than to predict the serviceability of the pipeline welds. Each welder knows that the X-ray crew is following closely behind him and can surely detect his operational failures – this is a driving stimulant to careful welding. In fact, the story is reliably told (by the manager of X-ray inspection of a major pipeline) that, on one occasion, their inspection crews ran out of film on a pipeline job. When they reported to the construction boss that they would have to stop radiography until more film arrived, the supervisor replied vehemently (and profanely) that they were not to interrupt radiography for a single minute. They were instructed to go through all of the operations of radiography (without using film) just as usual, since the welders would instantly recognize the stoppage in inspection and relax their care in welding.

Similar techniques can often be devised to control the work of personnel in in-plant operations. The results of immediate feedback by incontrovertible evidence from nondestructive tests (rather than a supervisor's opinion) gain immediate respect by skilled personnel.

Of course, such systems must be properly introduced and explained to production personnel, but in most instances, they will prefer such fair and impartial judgement to the possibly biased opinions of immediate supervisors.

Here is one example. In the critical production of brazed honeycomb stainless steel structures, utmost cleanliness in assembly is essential. When the X-ray images of the actual fingerprints of a specific worker (shown by failure of brazing alloy to wet the material) brought a reaction from his fellow workers, the percentage of defective products from the department immediately decreased. Where incentive group income depends upon quality of output, such measures can greatly influence productivity.

Supermarkets for Testing

Today, the situation in nondestructive testing is changing with amazing rapidity. Supermarket services, supplying all forms of nondestructive test equipment and services, are being developed. Firms with a complete line of nondestructive testing equipment and processes can advise the optimum available test method. The customer's problem can be solved more effectively by the correct test method or group of test methods for his requirements.

This trend is fully justified by the rapid development of nondestructive testing from the status of occasional applications in special product inspection to that of an essential component of mechanization and automation of production. To illustrate, no longer does the customer buy his own isotope and ionization gage, and attempt to develop some form of test device on his own. For the most part, he selects a proven firm which can provide a complete system to be integrated with his production-line operations. These well-engineered systems have been remarkably successful in many applications.

In conclusion, the measure of management's achievement through proper use of nondestructive tests will be evident in terms of the markets retained or developed, the reputation of the firm and the degree of customer satisfaction with its products, and the continuing profits of the company. Their origin can often be proved to be related to an intelligent management application of nondestructive testing – the greatest unexploited tool remaining fully under management control.

Defects That Nondestructive Tests Can Find

This group of pictures is designed to illustrate the wide variety of flaws which can be found in a product before it goes into service. Of course, many other types of defects may be produced by stress-corrosion, or the tensile, compressive, or bend stresses which can occur in service. They will be discussed in the articles to follow in this series.

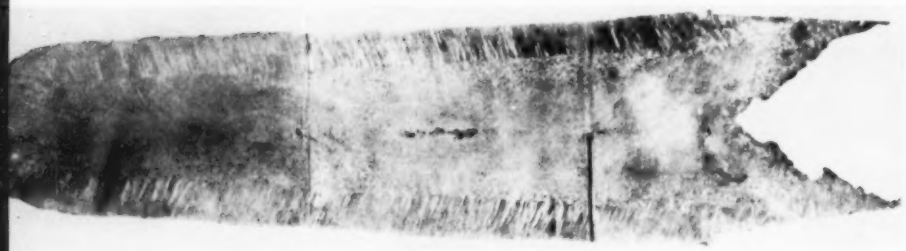


Fig. 1 – The Voids Which Extend Down the Middle of This Ingot Are Called "Secondary Pipe". Though invisible to the eye, they can be detected by ultrasonic inspection or radiography techniques

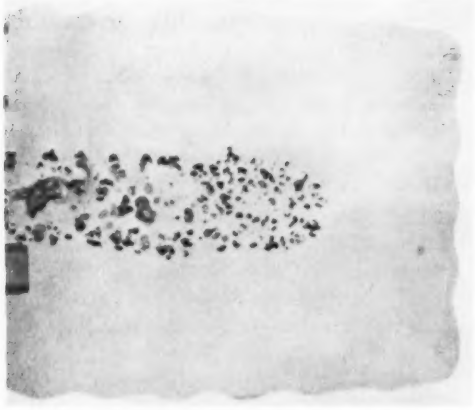


Fig. 2 – Shrinkage and Blowholes in an Ingot Section. Ultrasonic inspection methods are useful in locating such defects

Fig. 3 – Shrinkage Voids in a Trepanned Bar From a Rotor Forging. If this defect had gone undetected, the rotor could have burst in service

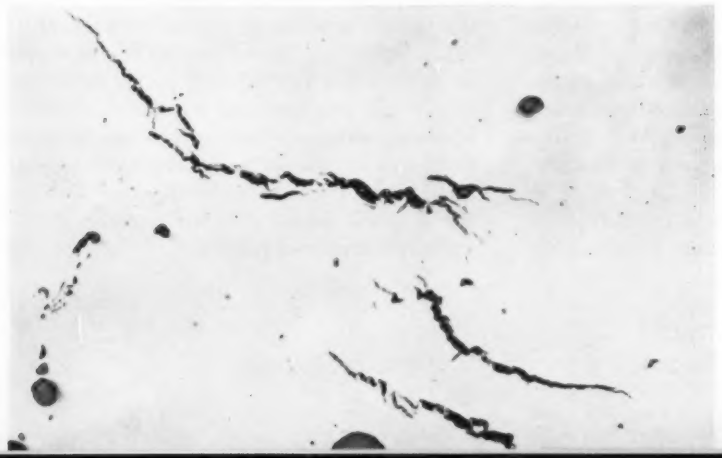


Fig. 4 – The Rotor Forging of Fig. 3 Also Contained These Discontinuous Cracks. With a little stress, such cracks can grow into one large crack and lead to failure

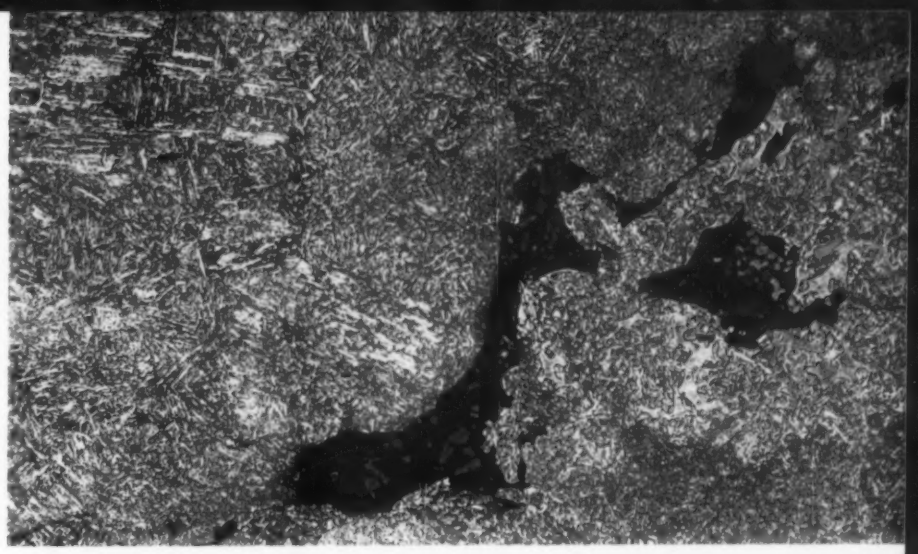


Fig. 5 – Slag-Type Inclusions Such as These Are the Result of Refractory Erosion From Furnace, Runner or Ladle. They are not malleable at the rolling temperature, and are difficult to detect by nondestructive test techniques. 100 ×

Fig. 6 – With Aluminum Deoxidation, Clouds of Alumina Inclusions (Such as Are Shown Here) Sometimes Appear. They can be detected by magnetic particle methods if they are at or near the surface (as in a machined part)

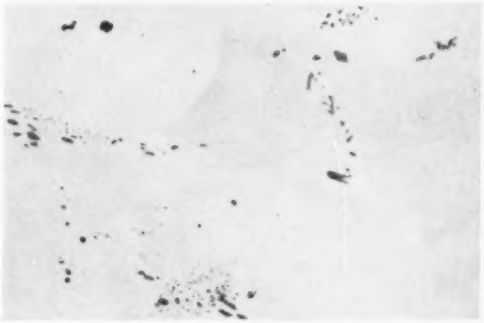
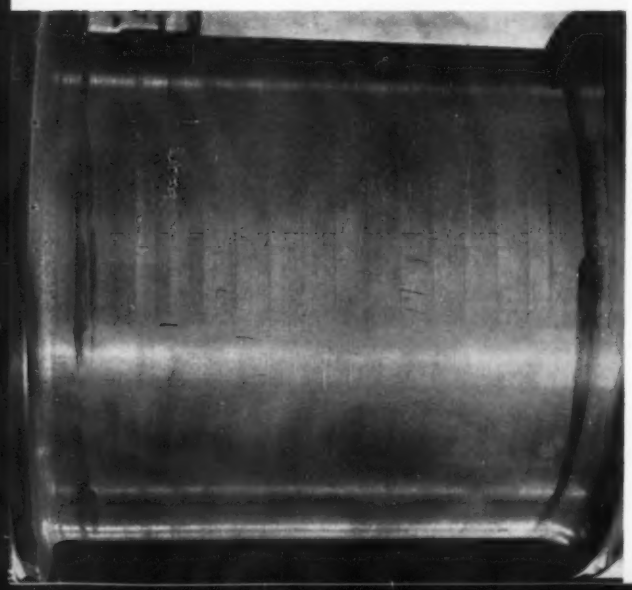


Fig. 7 – Manganese Sulphide Inclusions Sometimes Appear as Cloudlike Masses in Castings. Being malleable at the rolling temperature, they roll out into stringers in blooms and billets. In general, they are not detrimental, but under some circumstances they will be picked up by magnetic particle tests to appear as dangerous stringers

Fig. 9 – Magnetic Particle Indications of "Sand Splits" on a Rotor Journal. Originating from flux, spalled runner brick, or segregation of deoxidation products, these defects are of little concern unless they are located on bearing surface. (They sometimes cause pickup of babbitt from bearings)



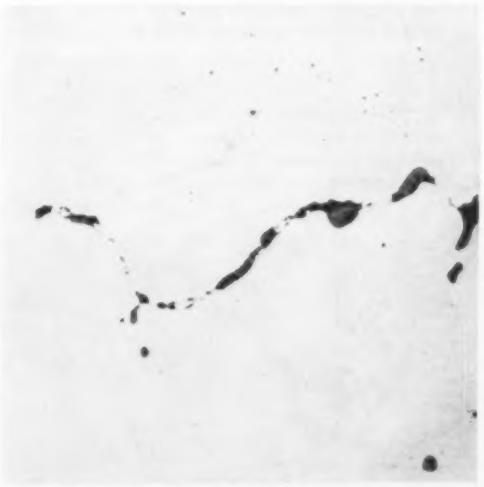


Fig. 8 – Cracks Connecting Inclusions in a Steel Forging. Ultrasonic tests will often find such defects

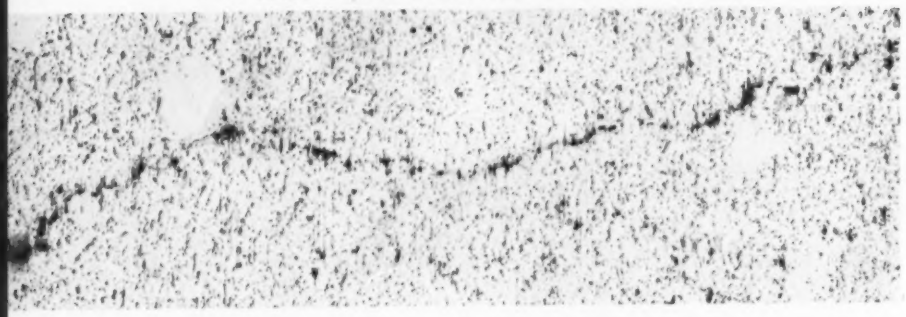


Fig. 10 – "Ghost Lines" Are Bright Streaks Which Sometimes Appear on Highly Polished Surfaces. As this sulphur print shows, they are actually bands of sulphide inclusions – they are usually found to be harmless

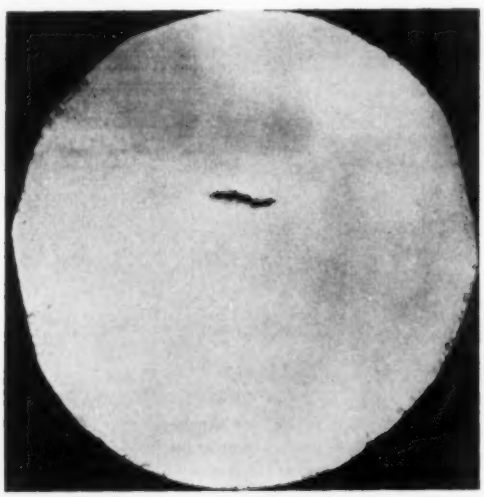


Fig. 11 – This is a "Forging Burst," a Serious Defect Which Is Cause for Rejection When Found. Though usually invisible to the eye, forging bursts can be detected by ultrasonic tests or radiography

Fig. 12 – Ruptures, Sometimes Called Flakes, are a Problem to Producers of Alloy Steel. Generally occurring in heavy sections which are improperly cooled after rolling or forging, they can be picked up by ultrasonic tests

Fig. 13 – Magnetic Particles Outlining Flakes in a Rotor Forging. If these defects had been previously detected by adequate testing, this rotor forging could have been scrapped before, rather than after, machining

Fig. 14 – Liquation in a Sheet of 24 S Aluminum. This incipient melting, which occurs when the sheet is overheated, leaves voids which can be detected by nondestructive tests

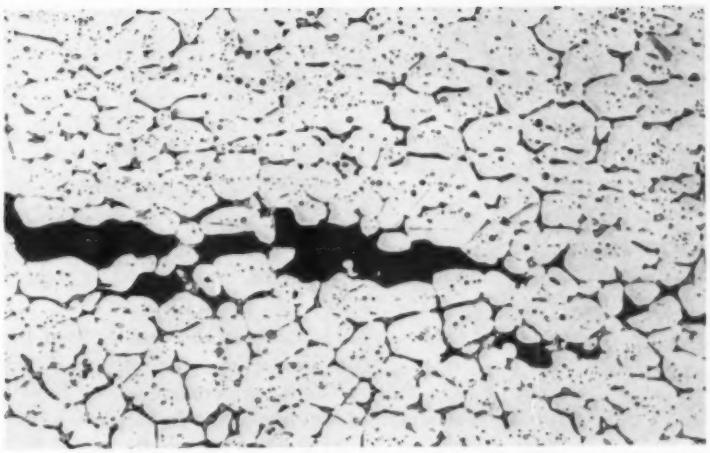
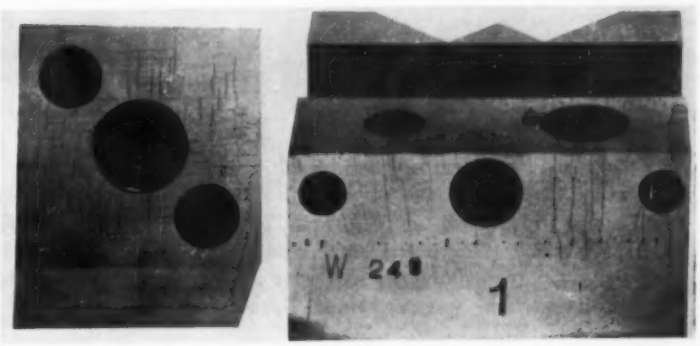


Fig. 15 – Grinding Cracks in a Hardened Die. These occur when the grinding wheel is too hard, the feed is too fast, or too little coolant is used. Fine grinding cracks are readily detected by using magnetic particle tests



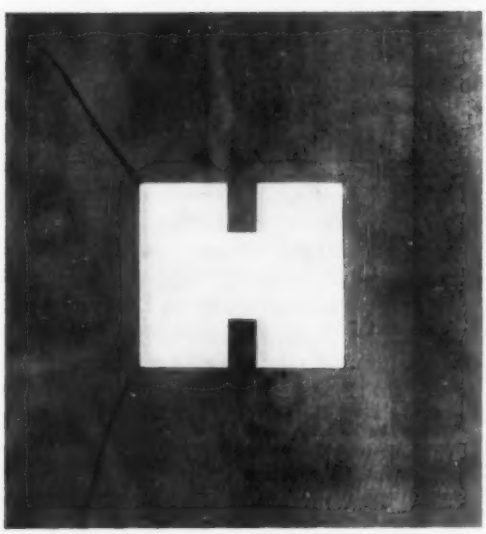
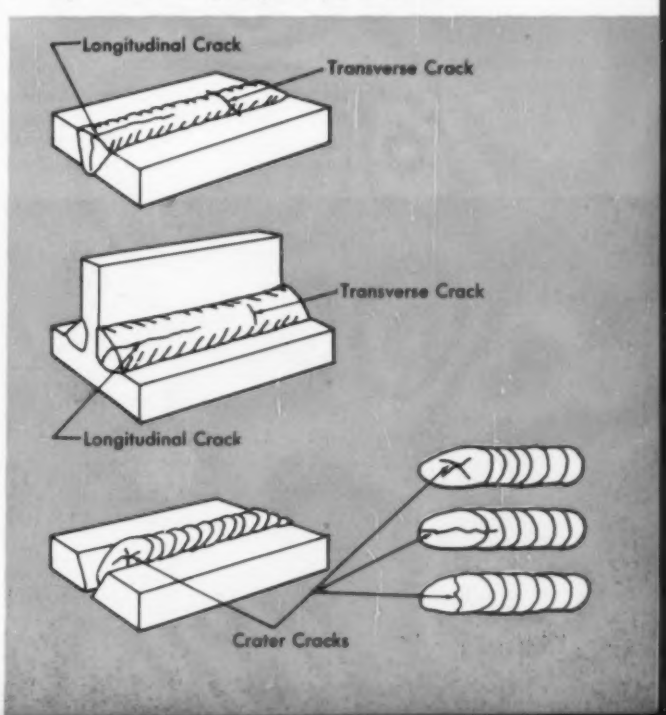


Fig. 16 – Quench Cracks Originating at the Sharp Corners of a Steel Die. Magnetic particle testing is useful in locating such defects, particularly when they are very thin and practically invisible to the eye

Fig. 17 – This Diagram Illustrates the Types of Defects Which Result From Improper Weld Procedures. Cracks such as these can usually be detected by magnetic particle tests



Properties of Ni-Al Age Hardening Steel

*By J. B. SEABROOK**

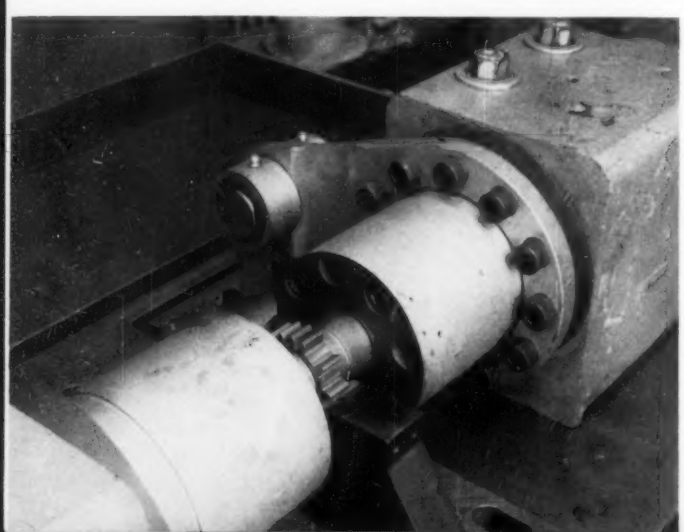
Because the nickel-aluminum steels (usually used for nitrided parts) have interesting aging properties – they do not overage despite long times at high temperature – they have been the source of much speculation and research. In this article the author concludes that the 5% Ni, 2% Al steel is potentially useful for precision gears despite its moderate impact strength. (J27d, Q-general; AY)

INTEREST IN THE BEHAVIOR of nickel-aluminum steels arose when a study was made of the effect of stress-relieving on a fabricated Nitralloy N gear prior to nitriding. As it turned out, the aging characteristics of Nitralloy N took on the semblance of an order-disorder reaction, and, as a consequence, the desired aging of the core during nitriding was not spoiled by stress-relief treatments which might otherwise be suspected of causing overaging.

Therefore, when the 5% Ni, 2% Al alloy was announced by the International Nickel Co. (see *Metal Progress*, February 1960, p. 91), we decided that its more intensive aging effects made a study of some of its properties worth while.

*Gear Metallurgist, Medium Steam Turbine, Generator and Gear Dept., General Electric Co., Lynn, Mass. The author wishes to thank G. R. Brophy and W. S. Mounce for supplying material and information, W. L. Sholl and A. E. Spaulding for making tests, G. Gleisberg for the dilatometer testing and Salem Toney for helpful discussion.

Fig. 1 – Universal Fatigue Testing Machine Adapted for Testing Pinions. The lever arm bolted to the chuck and extending to the left is driven by a mechanical oscillator



Aging Characteristics

Before discussing our results, however, a brief review might be in order. The interesting aging characteristics we have found with the nickel-aluminum steels can be summarized as follows: *(a)* Almost regardless of prior history (for example, normalizing, quenching and tempering up to 1100° F., quenching only, quenching to and holding at the aging temperature), the alloys age to a final hardness range characteristic of the aging temperature; *(b)* alloys do not overage even though held at temperature for 100 hr. or more (although a quenched specimen may go through a peak of higher hardness before leveling off at the characteristic hardness); *(c)* a specimen aged at one temperature and then aged at a higher or lower temperature will approach the hardness characteristic of the second temperature; and *(d)* slow rates of cooling from the "solution" temperature provide some initial hardening but do not prevent subsequent aging to essentially full hardness.

We were interested in determining the causes of these effects which are different from those in familiar precipitation hardening alloys. Was

an order-disorder reaction in the matrix or in domains of the matrix? Was it an order-disorder reaction in a precipitate? Was it a precipitate in this system (Ni_3Al, presumably) which went in and out of solution, reversibly, without losing coherency*? We as yet cannot answer these questions. But in any event, the fact that this alloy could age from a machinable condition to as high a hardness as Rockwell C-53 warranted further study of its mechanical properties.

Procedure

We began with considerable preliminary work† on normalizing, quenching, tempering and aging treatments. Before aging, the alloy is usually heat treated by normalizing at 1700° F., austenitizing at 1650° F., oil quenching (to Rockwell C-44 to 46) and tempering at 1275° F. (to Rockwell C-35 to 38). Aging at 975° F. yields a hardness of Rockwell C-46 to 49, while aging at 1050° F. yields a hardness of Rockwell C-37 to 40. We also found that tempering at 800° F. (instead of 1275° F.) and then aging at 975° F. produced a hardness of Rockwell C-51 to 54.

Consequently, we studied three conditions, designated A, B and C, respectively, for easy reference. All specimens were heat treated as previously described up through the quench; then one set was tempered at 1275° F. and aged at 975° F. (Treatment A); the second set was merely tempered at 1275° F. (Treatment B); and the third set was tempered at 800° F. and aged at 975° C. (Treatment C).

Next, tensile, fatigue, V-notch Charpy impact, and stress-rupture tests were made for each of these three conditions. Thermal expansion and dimensional change during aging were measured for Treatment A, and distortion from aging was measured for Treatments A and C. In preparing the specimens, excess stock was left on throughout the normalizing, quenching and tempering treatments. After this, the specimens were finish-machined, the relative machinability being noted, and the bars with Treatments A and C were aged. Two types

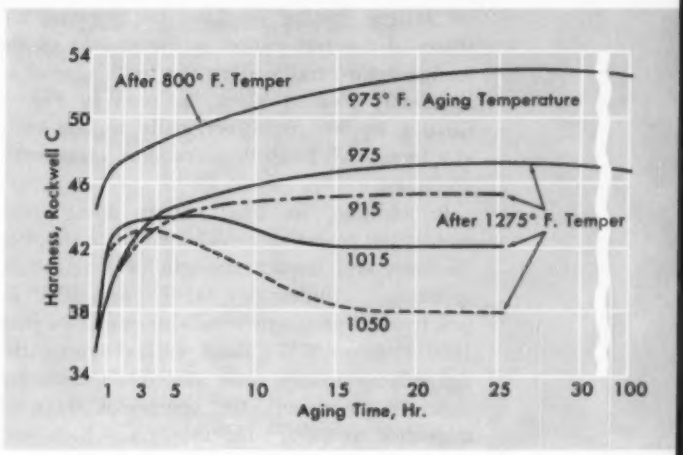
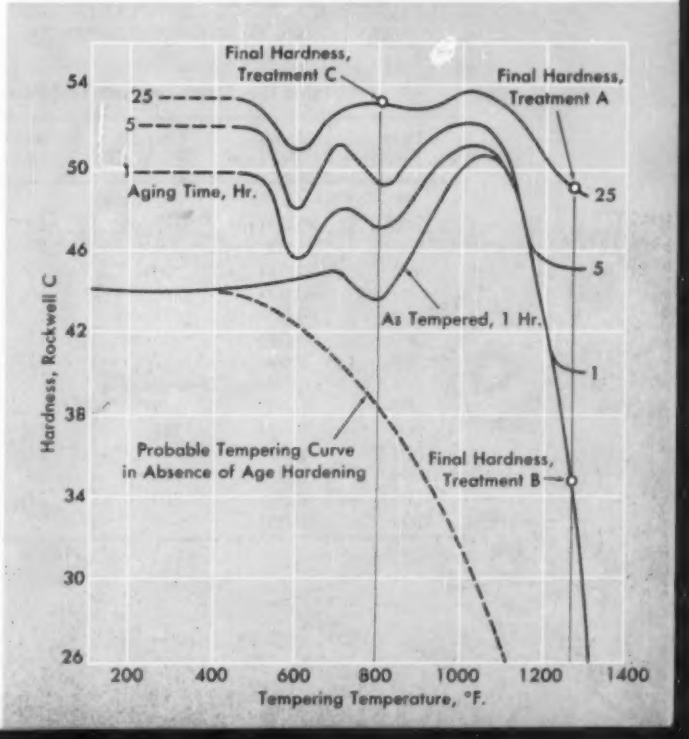


Fig. 2 – Aging Curves for 5% Ni, 2% Al Steel. Note that overaging does not occur despite the long times at temperature

of fatigue tests were made, one with standard unnotched Krouse bars on high-speed rotating cantilever beam machines, and the other with a 10-pitch, 20-tooth spur pinion having a ⅝ in. face width. The pinion test is done in a univer-

Fig. 3 – Effect of Tempering Temperature on Subsequent Aging at 975° F. After quenching, three different aging treatments were employed. For Treatment A, one set of specimens was tempered at 1275° F. and aged at 975° F.; for Treatment B, a second set was merely tempered at 1275° F.; and for Treatment C, a third set was tempered at 800° F. and aged at 975° F.



*See two articles by R. O. Williams: "Classification of Precipitation Systems", *Transactions* A.S.M., Vol. 50, 1958, p. 562, and "Aging of Nickel-Base Aluminum Alloys", *Transactions* A.I.M.E., Vol. 215, December 1959, p. 1026.

†Alloy composition: 0.23% C, 0.42 Mn, 0.25 Si, 0.013 P, 0.023 S, 0.55 Cr, 5.30 Ni, 0.24 Mo, 0.14 V, and 2.3 Al. Supplied by International Nickel Co., it was forged into bar (from a 4 by 4-in. billet) in the 2000 to 1700° F. range.

sal fatigue testing machine by gripping the shafts of the test pinion in the chucks of the torsion fixture and loading one tooth against an accurately located block, as seen in Fig. 1. Load is applied unidirectionally to one tooth at a time; each tooth thus becomes a transverse specimen.

In addition, we tried various aging treatments, and tentatively evaluated their effect on hardness and impact strength of longitudinal specimens. Underaging (at 975 and 1050° F.) was tried. Specimens were also quenched from 1650° F. into a 975° F. lead pot and aged. After aging (unavoidably, some austenite transformation also occurred), the specimens were oil quenched to room temperature and then tempered for 1 hr. at 975° F. This type of isothermal treatment was also used on impact bars to determine if improvement might be obtained by avoiding some temper embrittlement. Some as-quenched impact bars were also tested.

Forging this alloy was no problem, and machinability was also good despite the fairly high intermediate hardnesses at which the specimens were finish-machined. The material could also be turned, drilled, shaped, hobbed, shaved, threaded and sawed with little difficulty – or no more than occurs in machining 4340 at Rockwell C-35. Turning with carbide and high speed steel tools produced very long spiral chips which displayed no temper color. Even in Condition A (Rockwell C-48), the alloy was drilled without great difficulty. Furthermore, after aging, the specimens had an attractive, smooth, adherent surface of black oxide. (This suggests that a byproduct of this kind of treatment on finish-machined parts would be a black oxide at no cost.)

Figure 2, which depicts curves for several aging temperatures, illustrates the lack of overaging and the "leveling-off" feature mentioned previously. In Fig. 3, which illustrates the effect of tempering temperature on subsequent aging at 975° F., it will be noted that tempering at 800° F. results in the lowest pre-aged hardnesses and one of the highest aged hardnesses. Admittedly, the pre-aged hardness is not significantly lower than the as-quenched hardness. However, we selected Treatment C (tempering at 800° F.) because we felt it would lessen distortion after finish machining and aging.

Table I shows the results of the tensile tests. Good yield-to-tensile strength ratios were obtained, and (except for ductility) the values agreed with those which would be expected from a conventional quenched and tempered steel.

Table I – Results of Tensile Tests*

	Treatment A	Treatment B	Treatment C
Tensile strength	220,000 psi.	169,000 psi.	260,000 psi.
Yield strength			
0.2% offset	210,000 psi.	158,000 psi.	—
0.02% offset	202,000	152,000 psi.	—
Elongation in 2 in.	13%	17%	Nil
Reduction of area	40%	55%	Nil
True stress at fracture	287,000 psi.	256,000 psi.	260,000 psi.
Young's modulus	28,700,000 psi.	28,900,000 psi.	—
Rockwell hardness	C-47	C-36	C-53

*Average of three 0.505 in. diameter specimens.

Table II – Stress-Rupture Test Results

Test Temperature	Initial Stress	Time to Fracture	Elongation in 1 In.	Reduction in Area
		Treatment A		
900° F.	80,000 psi.	577 hr.	18%	40%
900	85,000	165	25	70
900	90,000	30	25	70
900	90,000	44	30	70
1000	65,000	31	17	45
1000	70,000	81	17	30
1000	75,000	17	27	80
		Treatment B		
900	70,000	529	Did not break	
900	80,000	387	18	60
900	90,000	0.5	24	70
1000	60,000	120	16	20
1000	60,000	210	14	15
1000	70,000	8	27	50

As for the fatigue data, Treatments A and B yielded results similar to those for conventional steels, but Treatment C has a ratio of endurance limit to tensile strength of 0.31. This low value presumably occurs because of brittleness. The fatigue strength of the test pinions was about equal to that of through hardened steel pinions at Rockwell C-35. The pinion with Treatment C was a little stronger than that with Treatment A. This reversal, as compared to the Krouse results, is either an error from insufficient testing or an effect of lower notch

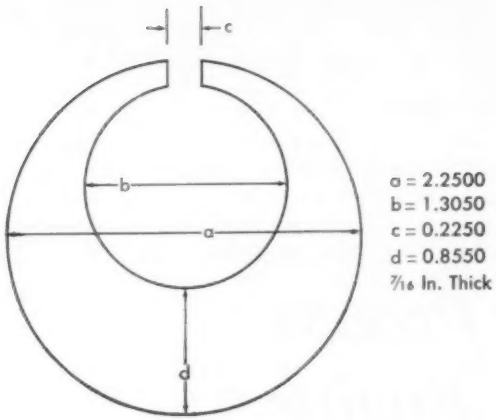


Table III – Distortion Test Results

Alloy	Dimension	Change in 0.0001 In.
5% Ni, 2% Al steel Treatment A	a	−12
	b	−4
	c	+2
	d	−4
5% Ni, 2% Al steel Treatment C	a	−14
	b	−4
	c	+4
	d	−5
A.I.S.I. 4340 Quenched and tempered (to Rockwell C-55)	a	+27
	b	+42
	c	+134
	d	+22

sensitivity in the unidirectional pinion test. Comparison of these unnitrided Treatment A and C results with tests we have made on nitrided Treatment A pinions shows that nitriding doubles the endurance limit.

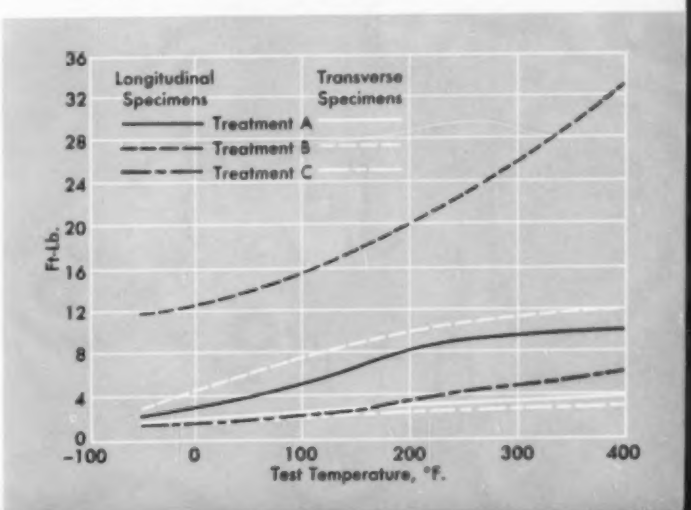
Though the impact strengths are low (as may be seen in Fig. 4), improvement is believed possible. For example, when specimens were aged at 1050 and 975° F., the room-temperature impact value was doubled at a sacrifice of only one Rockwell C hardness point (compared to Treatments A and C). Final hardness of the isothermally aged specimens was Rockwell C-53; that is the same as the hardness of specimens quenched to room temperature and then aged. No improvement in impact strength was found for the isothermal treatment. However, ferrite might be expected to form in the initial part of the treatment, and this would offset any improvement. The as-quenched bars gave a significantly high value of 28 ft-lb. at room temperature—that is, twice the value for Treatment B.

Stress-rupture results for the Conditions A and B are given in Table II. It is worth noting that the Treatment B specimens tested at 1000° F. aged enough during test to give strengths equal to those of the Treatment A specimens at a time-temperature parameter value of 33,000. Thermal expansion of alloy in Condition A is comparable to that of familiar alloy steels, namely 7.0×10^{-6} in. per in. over the range of 0 to 1000° F. Shrinkage of 0.0004 in. per in. occurs during aging, following a curve which is in direct agreement with the aging curve shown in Fig. 2. This shrinkage is a probable source of additional residual compression in a nitrided case, since it would occur while the case is being formed; it also accounts for reduced growth after nitriding.

Scaled-down specimens (sketched with Table III) were used to determine distortion which occurred on aging the alloy to Conditions A and C. Table III compares these results with those obtained in oil quenching and tempering 4340 to Rockwell C-55. Indications are that distortion in 5% Ni, 2% Al steel is low enough to permit finish machining before aging.

As a cautionary note, remember that these results are for one heat only. Future results may show deviations from the data and reveal critical aspects of the heat treatments. The indications so far, however, are that the 5% Ni, 2% Al steel is an alloy which provides moderate material cost, low processing cost, good forgeability and machinability, low distortion, strengths similar to conventional steels, and aged hardnesses up to Rockwell C-53.

Fig. 4 – Results of V-Notch Charpy Tests. Though these values are low, it appears possible to improve them



Staff Report

Chevrolet Adopts European Casting Process for Corvair Engine

Adoption of low-pressure casting for producing engine components in this country required some changes over European practice. To meet demands of high production, Chevrolet engineers built heavier machines and added automatic controls for regulating temperature, pressure and mold manipulation. (E12, T21b; Al)

WITH THE INTRODUCTION of the Corvair late in 1959, Chevrolet not only took a gamble on the engine-in-the-rear concept, but also built the engine, with few exceptions, of aluminum, and imported a casting process from Europe to make most of its components. Taking an idea from England which had spread to foundries on the Continent, Chevrolet engineers adapted low-pressure casting to the high-volume production requirements of the automobile industry and made it pay.

How Castings Are Made

Low-pressure casting may be described as a process between die casting and permanent mold casting. (It is often called low-pressure permanent mold casting.) Basic equipment, as shown in Fig. 1, includes a metal mold which is mounted on top of a sealed furnace. To make a casting, the pressure of the atmosphere in the furnace is increased. Metal rises up a tube called a stalk into the mold cavity. After a carefully measured time, pressure is released and the excess metal falls from the stalk back to the furnace. After a short chill time to assure complete solidification, the casting is ejected from the mold.

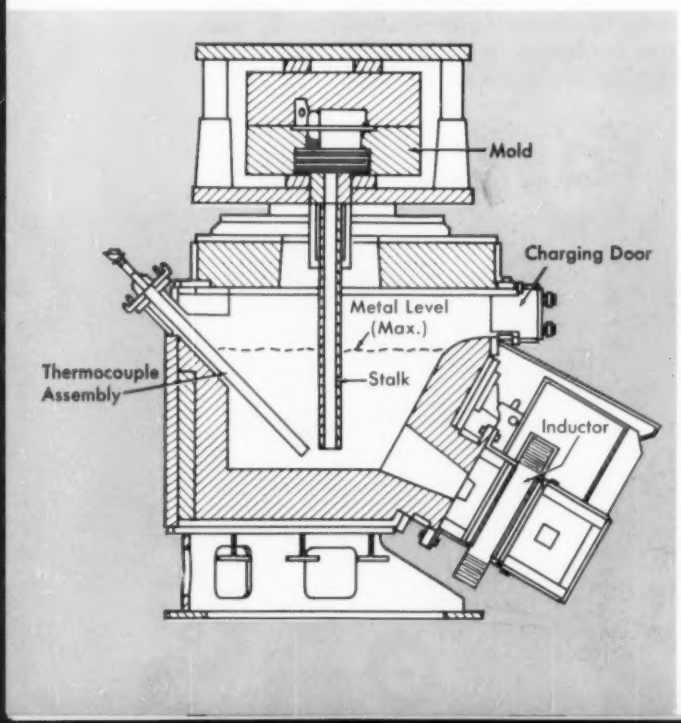


Fig. 1 – Low-Pressure Casting Equipment Includes Metal Mold Mounted on a Sealed Furnace. Part is cast by pressurizing the furnaces so that the metal rises up the stalk into the mold cavity

Chevrolet has found these advantages in low-pressure casting:

- Metal yield is high, for the most part over 95%.
- Equipment costs are low – less than die casting and about the same for permanent mold.
- Clean castings are obtained because sealed furnaces and metal drawn from below the surface minimize dross entrapment.
- Sound castings are produced without the need for risers. Cooling rate can be adjusted and directional solidification promoted by localized heating and application of mold wash.
- Productivity is relatively high. Castings weighing as much as 18 lb. can be made in less than 7 min., and more than one machine can be handled by one operator.

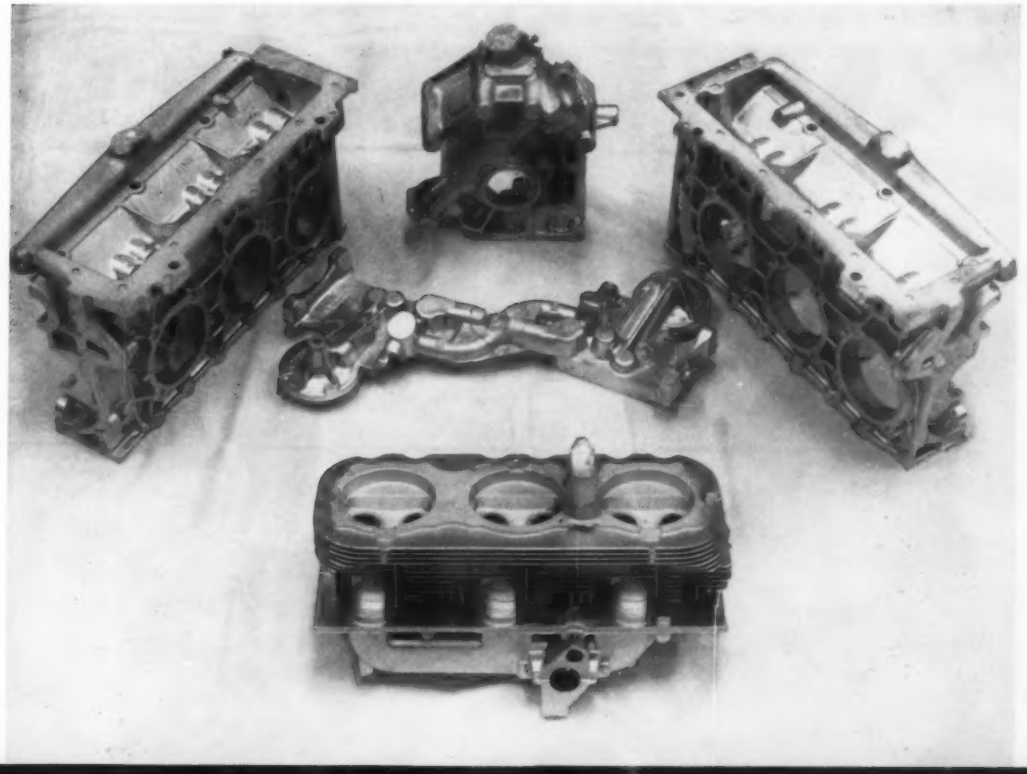
European Practice Changed

The basic difference in low-pressure casting between European and American practice is one of automatic control. In Europe most of the work in low-pressure casting – mold opening and closing, stripping – is done manually with rack and pinions. One man operates one machine. With Chevrolet, two and sometimes three machines are handled by a single operator. Mold closing and opening are done automatically by an arrangement of hydraulic cylinders and limit switches which move each mold component at the right instant. The problem was to maintain die tolerances and develop systems not affected by heat or dirt. Counter to European practice in which molds are matched to a particular machine, Chevrolet has made mold components which are interchangeable from one machine to another.

Although low-pressure casting is not used exclusively to make all of the aluminum castings at Chevrolet, it does account for most of them. Parts made by the process, shown in Fig. 2, include Corvair engine's right and left crankcase, cylinder heads, oil filter and generator adapter, and engine rear housing. All of these are made in 356 aluminum alloy which accounts for some 85% of the total metal used at the foundry. Other alloys include 380 (10%, for die casting) and D-132 (5%, for permanent mold casting).

Chevrolet now has about 70 low-pressure casting machines in operation and has room to expand. Hot metal is brought in from Reynolds Metals Corp.'s nearby reduction plant in 9000-lb. capacity transfer ladles at about 1650° F. These are first degassed (Fig. 3), then transferred to one of 16 induction furnaces at 1350° F. Each furnace has a capacity of

Fig. 2 – Low-Pressure Process Is Used at Chevrolet's Aluminum Foundry in Massena, N.Y., to Cast Corvair Engine Parts. Flanked by left and right crankcase castings are engine rear housing (top), oil filter and generator adapter (center) and one of two cylinder heads (bottom). Parts are cast in 356 aluminum alloy and aged at 400° F. for 4 hr. Castings shown are not solution heat treated



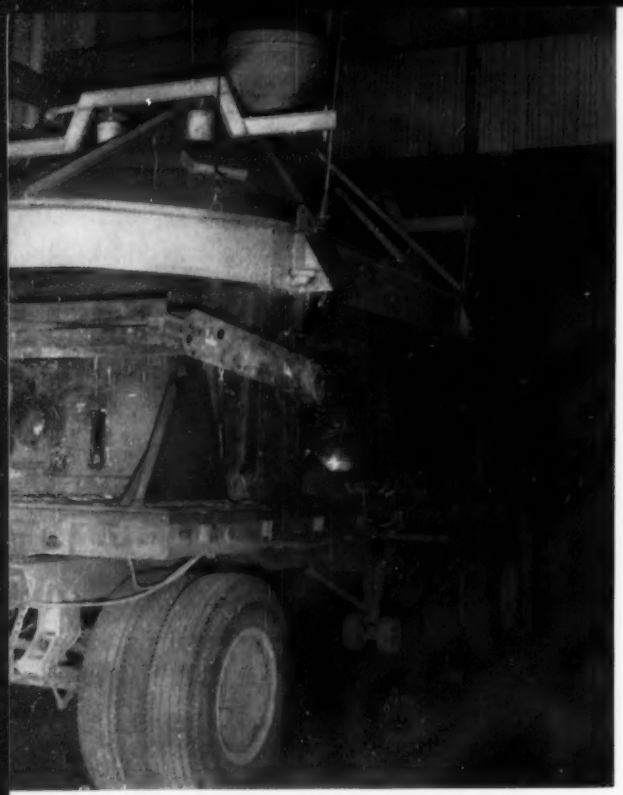


Fig. 3 – Molten Aluminum, Transferred From Nearby Reduction Plant to Foundry in 9000-Lb. Capacity Ladles, Is Degassed With Nitrogen-Chlorine Mixture Before Being Poured in One of 16 Holding Furnaces. Use of induction furnaces throughout the foundry (except in remelting) prevents excessive pickup of hydrogen by the aluminum

30,000 lb. The metal is checked for gas content by solidifying a sample under reduced pressure.

Chlorine Degassing

For degassing, Chevrolet first used chlorine but has changed to nitrogen-chlorine mixtures beginning with 75-25 nitrogen-chlorine. Eventual goal is a 90-10 ratio but this will depend on results. When 100% chlorine is used, it is unnecessary to degas after the first treatment except when a new furnace lining causes gas pickup or when scrap, runners and gates are remelted.

Magnesium is added to the metal in the holding furnaces to bring it up to 0.30% for 356 alloy. Aluminum-copper, silicon, and manganese are added to obtain the correct analysis for 380 or D-132 alloy. Then the metal is carried to the low-pressure machines in 1000-lb. transfer ladles toted by lift trucks (Fig. 4). Temperature of the metal in the machines depends on desired casting temperature and ranges from 1200 to 1350° F.

Table I – Casting Conditions for Corvair Engine Parts

	Pot Pressure	Pressure Time	Solidification Time
Left crankcase	4 to 7 psi.	190 to 200 sec.	80 sec.
Right crankcase	4 to 6	180 to 195	70
Rear engine housing	4 to 6	150 to 170	50
Cylinder head	3 to 5	300	120

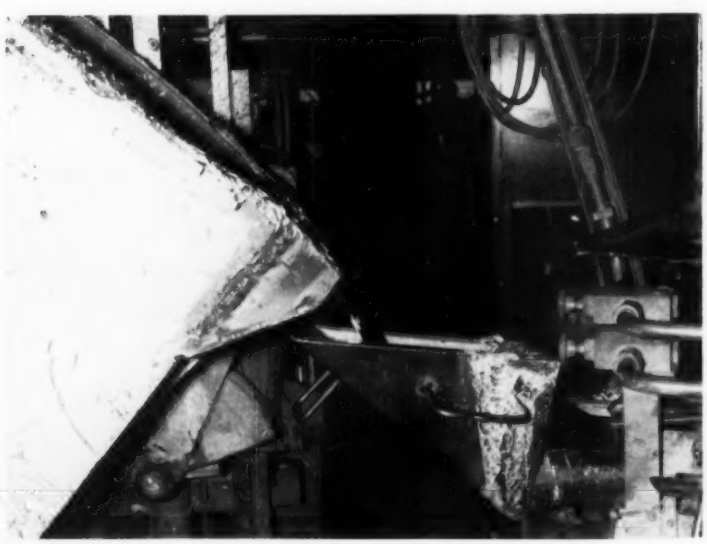


Fig. 4 – Aluminum for Casting Machines Is Transferred From Holding Furnace in 1000-Lb. Ladles Which Are Carried by Lift Trucks

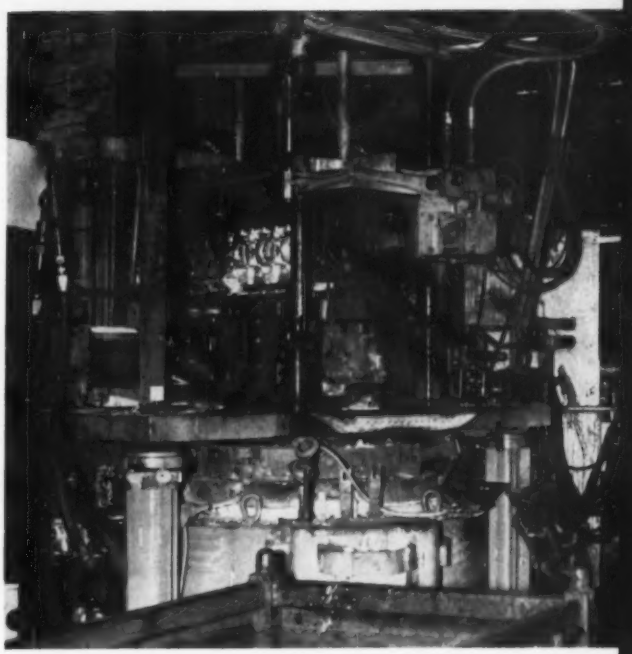


Fig. 5—Low-Pressure Casting Machines at Chevrolet Foundry in Massena, N.Y., Are Equipped With Automatic Pressure and Timing Controls. Casting shown here is one of the crankcase sections for Corvair engine. It is produced in about 4 min.

Variables

Besides pouring temperature, such variables as pressure, time for which pressure is applied and time permitted for solidification are important in low-pressure casting. In Europe the low cost of labor permits these to be controlled by the operator. At the Massena foundry, however, the need for consistent results during casting of large numbers of parts plus the high labor costs make it necessary to use automatic pressure and timing controls on the casting machines (Fig. 5). Casting conditions for major engine parts are given in Table I.

Cylinder Head Casting

Casting the cylinder head (Fig. 6) is one of the most difficult jobs. Exhaust ports and manifold intake must be formed by sand cores, and each head has numerous cooling fins made by casting the metal in molds containing 34 movable blades. These are withdrawn automatically in precise order after the casting solidifies.

The casting is sent to the cleaning area where the sand cores are removed and excess metal is trimmed off. It is then aged for 4 hr. at 400° F. and packaged for shipment to Corvair's engine assembly pant in Tonawanda, N.Y.

High yield, an inherent advantage of the low-pressure process, is demonstrated in casting the cylinder head. Total casting weight is 17.86 lb. In the trimmed condition the head weighs 17.50 lb., a yield of about 98%.

Coating Life Improved

Mold coatings which prevent the casting from sticking to the mold and also aid in getting directional solidification have proved the biggest problem in the past since the fins have only a 1° draft angle. Blades are changed every shift so that they can be cleaned. Usually, however, over 75 castings can be made before a new mold coating is needed.

Chevrolet is using a proprietary mix to which some additions have been made. Molds and blades are first given a caustic dip for ½ hr., are cleaned by wire brushing or light sand-blasting and heated to a temperature of 700° F. before being coated. They are held in a furnace until needed. Each cylinder head mold has two sets of fin blades and components which permit continuous operation of the casting machine while the spare set is being recoated.

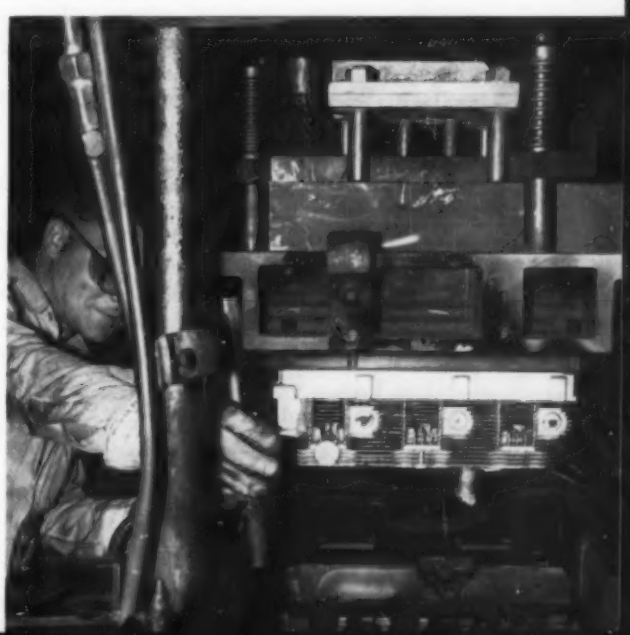
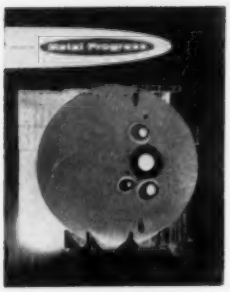


Fig. 6 – Cylinder Head Can Be Cast in About 7 Min. at Chevrolet's Aluminum Foundry. Cooling fins are cast in by using movable blades (lower mold) which are withdrawn after the casting has solidified. Intake manifold and exhaust ports are cored



Welding and Heat Treating a 60-Ton Cryogenic Vessel

By WARREN H. VETTER*

A huge storage tank for liquid oxygen (see cover) was fabricated by joining 5-in. thick segments of Type 321 stainless steel with 12,000 lb. of weld metal. The entire tank was annealed after welding. (K1, J23, SS, 2-63)

THE CRYOGENIC VESSEL shown on the cover of this month's *Metal Progress* was fabricated in the Alhambra, Calif., shop of the Southwest Welding and Mfg. Div. of Yuba Consolidated Industries, Inc. Designed to contain 8000 gal. of liquid oxygen at a pressure of 2000 psi., it measures 12 ft., 9 in. inside diameter and has a minimum wall thickness of 4⅜ in. Gores or orange-peel segments of the shell were formed from stainless steel plate almost 5 in. thick under a heavy hydraulic press.

The vessel serves as an example of one of the growing markets for the metalworking industry. Cryogenics, which deals with the generation, transportation and storage of liquefied gases at low temperatures, has taken on new importance. Rocket engines of the type that power our Atlas and Titan missiles, for example, require huge quantities of oxygen to support the combustion of the rocket fuel. Other engines are being developed to use hydrogen as a fuel. These gases must be stored and handled in liquid form; this means new problems in metal selection and fabrication.

*Chief Engineer, Southwest Welding and Mfg. Div., Yuba Consolidated Industries, Inc., Alhambra, Calif.

Metals Used Near Absolute Zero

In emphasizing the extent of the problem involved in the storage of these liquefied gases, we must first clarify the area of low temperatures that are involved in cryogenics. This is not the relatively warm temperature at which water freezes or even the −20 or −40° F. maintained in food freezers or encountered in the dead of winter in Wyoming or North Dakota. Instead, we are dealing with temperatures of −300° F. and colder.

Liquid oxygen is the warmest of the cryogenic liquids used in rocket engines. It has a boiling point just above −300° F., while liquid nitrogen boils at −320° F. Liquid hydrogen boils at −423° F. and liquid helium, which also finds use in missiles and space vehicles, boils at −452° F. This means that a container for liquid helium would have an operating temperature just 7° F. above the absolute zero point

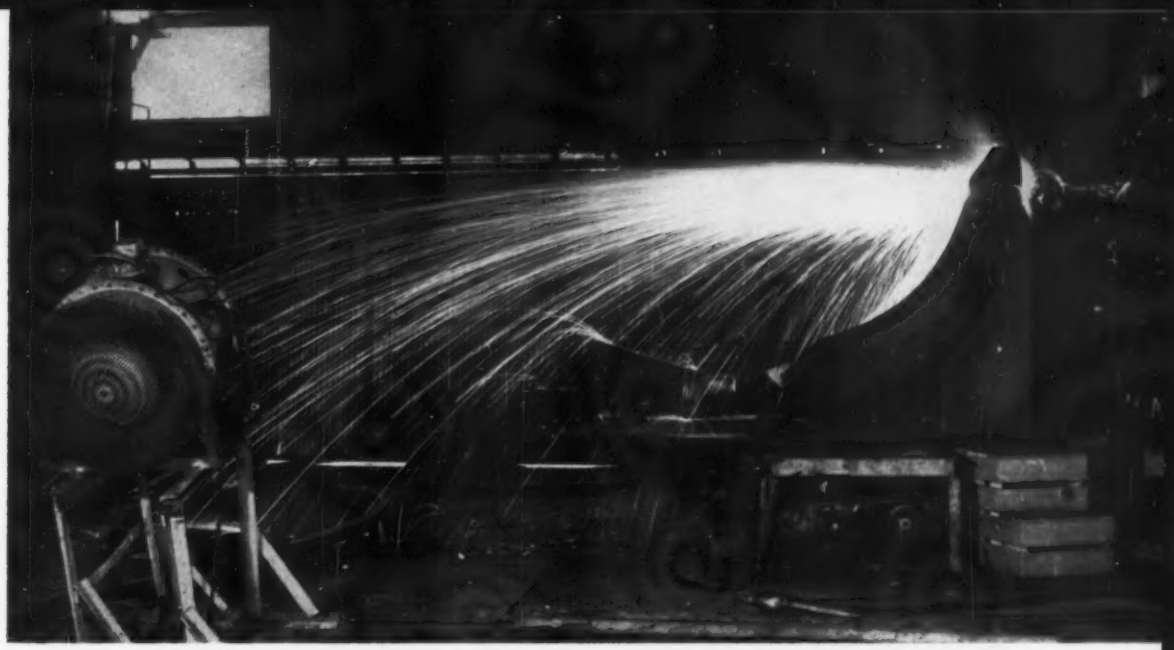


Fig. 1 – Thick Segment of Type 321 Stainless Steel, Formed in Large Press for 60-Ton Cryogenic Vessel (See Cover), Is Cut to Final Size

of −459° F. Not only do containers for liquefied gases operate at these low temperatures but, quite often, they are also pressurized at 2000 to 3000 psi.

Problems in Materials and Fabrication

This combination of low temperature and high pressure poses some difficult problems in the design and fabrication of containers. Although the tensile strength, yield strength and modulus of elasticity of most materials increase as temperature decreases, one property, namely toughness, often falls off quite rapidly.

Ordinary carbon steels are practically useless for service at temperatures below zero because they become almost as brittle as glass. Some fully killed carbon steels which are treated with aluminum to provide a fine grain can be used safely down to −50° F. Low-nickel steels – one containing 3.5% Ni, for example – can be used down to −150° F. For anything below that temperature, however, we must use such metals as the 9% nickel steels, the austenitic stainless steels in the 18% Cr, 8% Ni range or certain nonferrous alloys, nickel-base alloys such as Monel or Inconel. Many aluminum alloys are, of course, also suitable for low-temperature service.

Precautions in Design

Design and fabrication of cryogenic vessels require that we take precautions that are not necessary in structures intended for service at room temperature and above. We must use butt welds exclusively – no lap welds are permitted; we must join parts of unequal stiffness with a gradual transition and streamline welded joints by grinding to promote a smooth flow of stresses and to avoid areas of stress concentration; we use no intermittent welds and we change thicknesses gradually to avoid re-entrant corner stress-raisers; finally, we select the heat treatment with care and fully radiograph all welds both before and after heat treatment.

Stress raisers are particularly important. Although avoided in most design and fabrication, they are especially dangerous at low temperatures. Here, that quality of toughness enters in again. For low-temperature pressure vessels, impact tests of the base metal, weld metal and metal in the fusion or heat-affected zone are made. All must exhibit an impact strength of 15 ft-lb. when treated at a temperature as low as or lower than the service temperature of the vessel.

The cryogenic tank shown on the cover is fabricated from Type 321 stainless steel. Like other austenitic alloys such as Types 304 and 347, it retains its toughness at −325° F. and is thus suitable for containers of liquid oxygen and liquid nitrogen. Recently, it has been found that these stainless steels are also suitable for operation down to −452° F. and can, therefore, be used in containers of liquid hydrogen and liquid helium.

As an indication of the enormity of the task

Fig. 2 – Joining Spherical Segments and Attaching Nozzles and Fittings Required 12,000 Lb. of Weld Metal. Sections are almost 5 in. thick

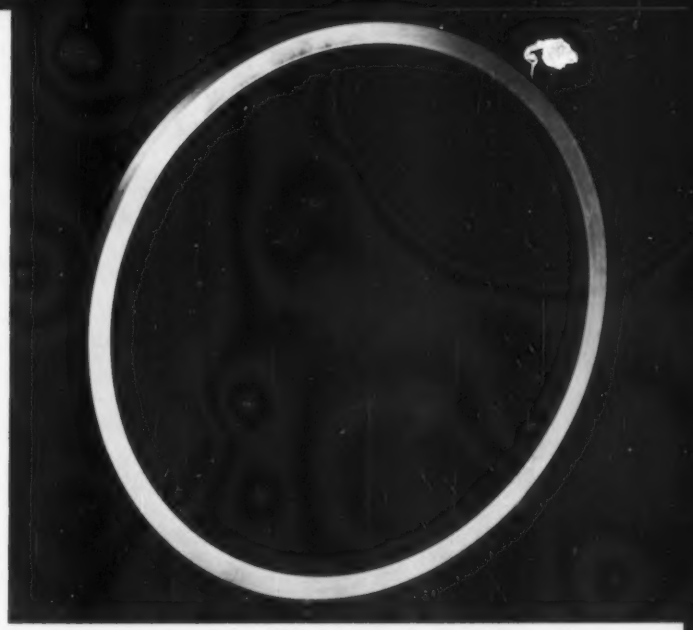
of welding the spherical segments which make up the vessel and attaching nozzles and fittings, it is worthy of note that over 12,000 lb. of weld metal was required for this vessel. For some of the forged stainless steel attachments, where the total depth of weld groove exceeded 11½ in. because of the configuration and reinforcement required for the openings, almost 400 passes of manual weld were required.

Although Type 321 is suited for low-temperature service, it does present certain welding problems that are not encountered in the more commonly used stainless steels of the 300 series. This titanium-stabilized grade is crack sensitive. Cracks in welds are never desirable, but they are especially undesirable in welds for low-temperature services. This made it essential not only to exercise close control of welding procedures but also to select carefully the chemistry of the welding electrodes to avoid weld cracking while at the same time maintaining the required weld ductility. A modified Type 347 stainless steel electrode with the ferrite range closely controlled – high enough to eliminate weld bead cracking, yet low enough to maintain low-temperature ductility – was chosen. This, coupled with low heat input through the use of small diameter electrodes and multiple weld passes, produced excellent welds which passed radiographic inspection and impact tests with no difficulty.

Heat Treatment

After all welding had been completed, the entire vessel was annealed. It was slowly heated to 800° F., and held for 5 hr. to allow the temperature to equalize through the varying thicknesses at the nozzle connections. The vessel was then raised slowly to 1850° F. After 5 hr. at 1850° F., it was removed from the furnace (see cover) and air cooled.

Following a hydrostatic test to 3000 psi., the 60-ton sphere was transported by truck to Edwards Air Force Base in California's Mojave Desert. Here it was surrounded by a spherical vacuum-tight jacket, 15 ft., 6 in. in diameter and placed in a rocket engine test stand operated by the Rocketdyne Div. of North American Aviation, Inc. The annular space between the stainless steel sphere and the outer jacket was then filled with powder insulation and high vacuum pulled in the annulus to create what might best be described as a giant thermos bottle, so well insulated as to allow liquid oxygen at −300° F. to be stored in the 120° F. desert heat with only negligible loss.



Ring Forged From Astroloy. This ring is 25 in. in diameter and weighs 50 lb.

Advances in High-Temperature Materials

How to Forge Astroloy

*By JOHN LUCHOK**

Large forgings, up to 1000 lb. in weight and 35 in. in diameter, are now being made of this alloy, the newest member of the nickel-base superalloys. Continuing research is expected to make the alloy even more useful as time goes on. (F22; Ni-b, SGA-h)

ASTROLOY, ONE OF THE NEWEST SUPERALLOYS, has very good tensile and stress-to-rupture properties, particularly above 1400° F. Another advantage: Because of the large amount of aluminum, 3.5%, the density is 0.287 lb. per cu.in. which makes it lighter than other superalloys of the same type. Thus, Astroloy is attractive for applications in airborne power plants because static weights can be lower and mechanical stresses (for given rotational speeds) can be reduced.

As a consequence, Wyman-Gordon engineers surmised that the alloy could be very useful for turbine wheels or disks in jet or missile engines, where other similar nickel-base alloys would be marginal or unusable. When we began to evolve the necessary techniques for forging Astroloy, our first experiments were directed at getting fundamental data on melting and casting characteristics, optimum chemistry, and forging variables, along with all of their interrelated effects. Starting with a series of 50-lb. forgings, we worked out the critical variables and placed them under control. After that, our efforts were directed toward producing large parts, some of which weighed as much as 400 lb. and were up to 35 in. in diameter.

As early as possible in our research, we began

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Fig. 1 – Microstructure at Mid-Radius of Astroloy Disk, 35 In. in Diameter. After forging, the disk was heated at 2100° F. for 30 min., air cooled, heated at 1400° F. for 16 hr. and air cooled. Etched in Fly's reagent; 100 ×

to work toward increasing the sizes of heats and parts. (Past experience with similar materials has shown that many of the problems that arise in producing full-scale components either do not exist or are not apparent when working with small "experimental" heats or parts.) Because of Astroloy's high aluminum and titanium contents and its sensitivity to gaseous contamination, all melting was performed in our vacuum melting facilities. The alloy must be cast with particular care because of its complex composition. However, because of the inherent adaptability of the induction vacuum melting process (cast structure and segregation can be controlled through the use of properly designed molds and pouring practices), no unusual casting problems were encountered. A microstructure taken from one of the experimental Astroloy forgings is shown in Fig. 1.

Initially, we investigated the effect of various forging temperatures (ranging from 1850 to 2100° F.) on small billets, our work being based on forging experience with similar alloys. We found the optimum forging temperature to be in the 2075 to 2125° F. range. To minimize heat loss in the forging (which can result in surface rupturing), we found it important to keep the transfer time from furnace to forging press to an absolute minimum. Our best results occurred when the time for all parts was kept below 20 sec. Smaller parts naturally required more rapid transfer than larger ones. We also found it desirable to use slower deformation rates than with alloy steels or with some of the less "exotic" high-temperature alloys. Forging rates, of course, vary with size and shape.

Next, we began the "scaling up" phase by working to forge a shape 35 in. in diameter. Because a number of forgings and heats were involved, we employed statistical methods to determine minimum properties accurately. All pieces of stock used were successfully finish forged, and were given a heat treatment which had been devised for Astroloy sheet. (Solution at 2100° F. for 30 min., air cool, age at 1650° F. for 4 hr. and air cool – this heat treatment, incidentally, may not be optimum for forgings.) We then ran tensile and stress-rupture tests to establish mechanical properties; these values are shown in Fig. 2 and 3.

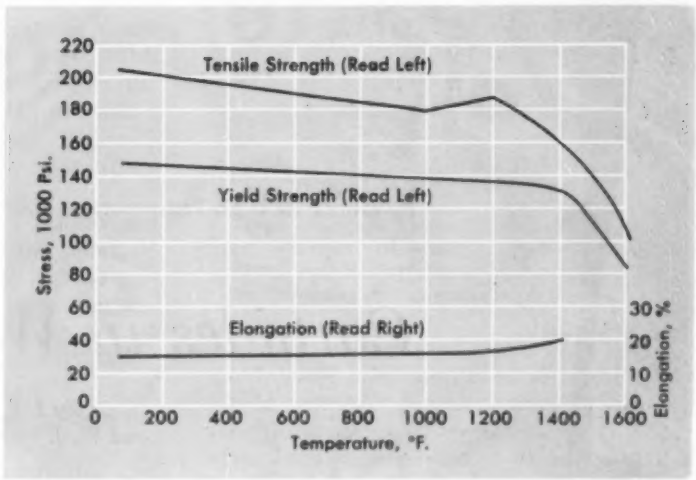


Fig. 2 – Tensile Strength, Yield Strength (0.2% Offset) and Elongation of Astroloy at Various Temperatures

Within a little over a year this program was completed, and we can now produce wheel and disk forgings (of simple shapes) up to 40 in. in diameter. In addition, enough property data have been acquired so that we can guarantee the following minimum mechanical properties on such forgings (heated to 2100° F. for 30 min. and air cooled):

	Room Temperature	1400° F.
Ultimate strength	190,000 psi.	150,000
0.2% yield strength	138,000	122,000
0.02% yield strength	127,000	110,000
Elongation (in 2 in.)	8%	10
Reduction in area	10%	12

Stress-rupture tests on a smooth bar, heated to 1400° F. for 16 hr. and air cooled are:

Temperature	1800° F.
Stress	20,000 psi.
Life	25 hr.
Elongation	7%

To date, we have successfully produced wheel forgings which weigh up to 1000 lb.; still larger forgings of this alloy are being considered. We are also getting additional property data (under test conditions other than those so far used) to further establish Astroloy's suitability for projected applications.

Future Work

At the present time, we are investigating a heat treatment which is expected to increase over-all tensile strength. For example, we are investigating the possibility of rapid quenching (such as with oil and water) following solution-

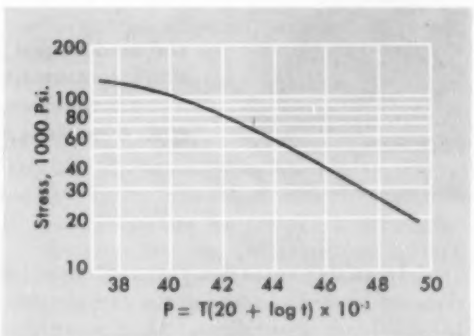


Fig. 3 – Larson-Miller Parameter Plot for Astroloy

ing. Preliminary test data from small samples have shown tensile and yield strength to increase up to 15%. So far, however, our research has barely scratched the surface. In the near future, we expect to attain a much greater variety of forging shapes. For example, work has already commenced on a systematic investigation of a number of forging and composition variables from which an optimum practice may be obtained. We are also gathering fundamental information concerning the response of the alloy to the combined effect of various heating and reduction operations. Simultaneously, heat treatment will be varied in an effort to bring about substantial increases in strength. All in all, it seems certain that Astroloy will take its place as a first-magnitude member in the galaxy of superalloys now available.

Waspaloy Turbine Blade Forged and Shaped at the Steel Improvement and Forge Co.

Advances in High-Temperature Materials

Carbides in Waspaloy

*By J. F. RADAVICH and W. J. PENNINGTON**

The predominant carbide in this superalloy is MC, which contains titanium, nickel, molybdenum and zirconium. Aging breaks down this phase, and $M_{23}C_6$ forms at grain boundaries and within the grains. (M26r; Ni-b, SGA-h)

IN RECENT YEARS many attempts have been directed toward identifying the carbide phases in nickel-base superalloys. Most investigators agree that one of the primary phases occurring in these alloys is Ti(C,N) with a minor amount of TiN being present. The other carbide phases, M_6C and $M_{23}C_6$, may also be present, depending upon composition and heat treatment. The first of these, M_6C, is often observed in alloys containing over 5.0% Mo, while the $M_{23}C_6$ type has been seen in most high-temperature alloys.

To supplement this previous work, we decided to investigate the carbides in Waspaloy, a typical superalloy. Three heats of Waspaloy (vacuum induction melted) were selected. Our idea was to determine the effects of solution heat treatment and subsequent stabilizing and aging heat treatments on the occurrence of the carbide phases. Representative samples from each heat were divided into two groups. The first group was solution treated for 4 hr. at 1975° F. and air cooled to room temperature, while the second group was solution treated for 4 hr. at 1975° F., air cooled, stabilized for 24 hr. at 1550° F., air cooled, and then aged for 16 hr. at 1400° F. After electrolytic polishing and etching, replicas were taken from each sample, shadow cast with chromium, and examined in the electron microscope. Finally, residues (obtained by acid digestion) were examined structurally (by X-ray diffraction) and chemically (by X-ray fluorescent means).

*Physics Dept., Purdue University, and Research and Development Dept., Universal-Cyclops Steel Corp., Bridgeville, Pa., respectively.

Microstructures

A typical microstructure for a heat in the solution treated condition is illustrated by Fig. 1. It consists of carbides in an austenitic matrix. For the most part, the carbides occur in a dispersed pattern, but they also appear to align and form small chains. This "chain-like" carbide formation is illustrated in Fig. 2; it is comparable to similar carbides in other nickel-base superalloys.

In addition to these carbide chains (which occurred in all samples regardless of heat treatment), a grain-boundary carbide was observed

in samples that were solution treated, stabilized and aged. Though the solution-treated material showed only large particles in the matrix, there were faint traces of a gamma prime (Ni_3AlTi) phase occurring in the grains. This indicated that the cooling rate through the gamma range was not fast enough to avoid a limited amount of precipitation. Figure 3 shows typical grain and grain-boundary structures in solution-treated Waspaloy.

Electron microscope studies of the samples that were solution treated, aged and stabilized indicated a great deal of uniform Ni_3AlTi precipitation in addition to the large particles occurring in the matrix. A heavy grain-boundary phase also came out of solution. In addition, a secondary precipitate was observed; it started from the grain boundaries or from the massive particles in the matrix.

Detailed studies of the solution-treated and aged samples indicated that the size and distribution of the gamma prime precipitate were essentially the same in all of them. Also, the heavy grain-boundary phase precipitated before the secondary matrix. The latter, which often formed as platelets, was considerably finer than the grain-boundary phase.

X-ray diffraction data are listed in Table I; they show the type of structural phases present, along with the lattice parameters and the relative intensity of all phases within each sample. Apparently, the primary precipitating phase in the solution-treated samples is TiC, though smaller amounts of TiN are also present. No other phases were detected; this indicated that all of the stringers observed in the light microscope are formed by alignment of TiC particles.

In a structural analysis of this sort, it is difficult to differentiate between pure TiC phase and a TiC phase containing alloy additions because both have lattice parameters of about 4.32 A. Pure TiN, however, can easily be identified; it has a lattice parameter of about 4.25 A. Samples that were solution treated and aged also contained an $M_{23}C_6$ type carbide, but there was no indication of an M_6C carbide.

The $M_{23}C_6$ phase, in the solution-treated-plus-aged samples, is rich in chromium. As would be anticipated, it also contains small amounts of cobalt, molybdenum and nickel. This phase has a lattice parameter of 10.65 A. which agrees quite well with that of $Cr_{23}C_6$, 10.628 A.

According to recent analysis, $M_{23}C_6$ carbides have a lattice parameter of 10.58 A. With

Fig. 1 – Carbide Formations in Solution-Treated Vacuum Induction Melted Waspaloy. These carbides appear in the austenitic matrix as chains and as discrete particles. 100 ×

molybdenum and nickel in solution, this value should increase or decrease depending upon the relative concentration of each element. However, if molybdenum and nickel are balanced, the observed lattice parameter could approximate that of pure $Cr_{23}C_6$. Cobalt in the $M_{23}C_6$ phase would probably result in a lower lattice parameter.

The main precipitating phase in the solution-treated samples is high in titanium and molybdenum, with lesser amounts of chromium, nickel and zirconium. Since the X-ray diffraction data listed in Table I indicate that only TiC and TiN phases are present, it is believed that the molybdenum, chromium, nickel and zirconium are in solution with a low-parameter TiC phase. This would result in parameters equivalent to the pure TiC phase. In this inves-

Fig. 2 – "Chain-Like" Formation Illustrating the Aligning Tendency of Massive Carbides. 10,500 ×

Table I – X-Ray Difraction Data

Heat	Condition	Phase	Intensity*	Lattice Parameter
A	Solutioned	TiC	VVS	4.31
		+TiN	W	4.25
A	Aged	TiC	S	4.31
		$+M_{23}C_6$	S	10.67
		+TiN	W	4.24
B	Solutioned	TiC	VVS	4.32
		+TiN	MS	4.25
B	Aged	TiC	S	4.31
		$+M_{23}C_6$	VS	10.65
		+TiN	M	4.24
C	Solutioned	TiC	VVS	4.32
		+TiN	VW	4.24
C	Aged	TiC	S	4.31
		$+M_{23}C_6$	VS	10.66
		+TiN	W	4.24

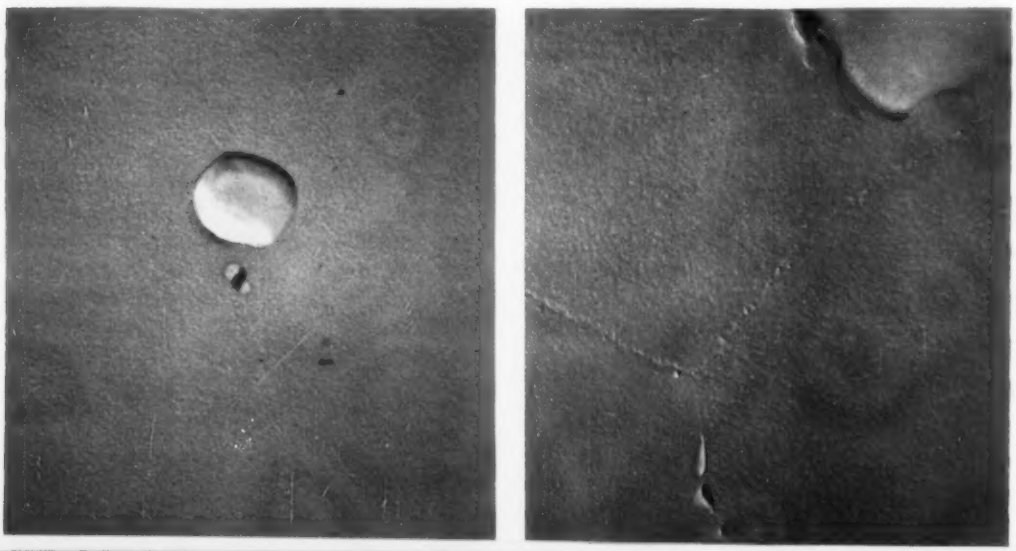
*Code: VVS — very, very strong; VS — very strong; S — strong; MS — medium strong; M — medium; W — weak; VW — very weak.

tigation, this is probably true, because zirconium would act to increase the lattice parameter. Conversely, nickel and molybdenum would act to decrease the lattice parameter of the primary carbide phase. Under the circumstances, it seems that the carbide observed in the solution-treated samples should more correctly be typed as an MC carbide where the M consists of a solid solution primarily of titanium and molybdenum with small amounts of nickel, chromium and zirconium.

The effects of heat treatment on the MC carbide are apparent in this investigation. In all of the heats investigated, the relative intensity of this carbide phase decreased with additional heat treatments, indicating that this phase breaks down during stabilizing and aging heat treatments.

After reviewing the various studies discussed here, it is apparent that the primary carbide phase in vacuum induction melted Waspaloy is an MC type carbide. This phase is high in titanium and molybdenum but smaller amounts of nickel, chromium and zirconium are also included. Subsequent aging appears to break down this phase and a secondary carbide precipitate ($M_{23}C_6$) forms. This secondary phase is predominantly chromium-rich, but also contains small amounts of nickel, molybdenum and cobalt. The $M_{23}C_6$ phase forms primarily at the grain boundaries; precipitation of this phase within the matrix then ensues. This precipitation originates at either the grain boundary or from the massive MC particles.

Fig. 3 – Representative Structures of Solution-Treated Waspaloy. Massive carbides appear within the grains, and smaller carbides, outline the boundaries. 10,500 ×



A New High-Temperature Alloy

By JOHN MAXSON*

Devised for service above 1800° F., this new nickel-base alloy, termed RA-333, contains 25% chromium, and 3% each of molybdenum, cobalt, and tungsten. Its excellent creep-rupture properties, low coefficient of expansion, and good oxidation resistance have made it useful for critical parts in heat treating furnaces. (Q-general, 2-62, W27p; Ni-b, SGA-h)

BUILDERS AND USERS of high-temperature furnace equipment continually demand better materials for their muffles, retorts, radiant tubes, fixtures and related furnace parts. On the surface, the procurement of a material to answer this need would seem relatively simple, particularly since there are a number of excellent superalloys already available. However, it should be borne in mind that most of these new alloys are produced in limited quantities by special techniques. Under such circumstances, some new sort of high-temperature alloy is called for. This need, we feel, has now been answered.

As a general purpose alloy for use in a broad temperature range, our alloy – which we call RA-333† – was built to definite specifications. We wanted it to have good strength above 1800° F., adequate resistance to oxidizing, carburizing, nitriding and other atmospheres, along with reasonable fabricability. We also considered cost and availability.

The Program for Research

Our first step was to survey all known existing alloys to evaluate their chemical compositions, along with their mechanical properties at temperatures and in atmospheres which they might encounter. Next, we "blueprinted" a new alloy as we thought it might exist. To explain further, since oxidation resistance is most effectively promoted by chromium, we immediately decided to add as much of the element as possible. However, forgeability is a limiting factor so we decided on an arbitrary limit of 25% Cr. Since a further reduction in iron content was desired (for improved oxidation resistance), we included 45% Ni in the tentative formula. Here, the strength reduction which occurs when nickel content is increased was a limiting factor. There are plusses, of course. Nickel adds corrosion resistance, ductility, low coefficient of expansion, and resistance to thermal shock. In addition, we thought that a relatively high percentage of nickel would probably promote forgeability and grain refinement, even though some strengthening elements would be required.

In conventional heat resisting alloys, silicon promotes oxidation resistance, and, even to a greater degree, resistance to the carbon and nitrogen found in furnace atmospheres. However, since silicon has little added effect over 1.5%, it was limited to a nominal 1.25%.

*Rolled Alloys, Inc., Detroit.

†U. S. Patent No. 2,955,934.

The strengthening elements which we could use included tungsten, molybdenum and cobalt. Of these, molybdenum is probably the most potent for high-temperature strength, but we decided to limit it to avoid hazards of catastrophic oxidation. Cobalt, if required in very large amounts, appeared too costly. Though we recognized the strengthening effect of tungsten, its cost and possible influence on oxidation resistance, stability of the alloy, and forgeability required more investigation.

Table I – Mechanical Short-Time Properties of RA-333

Temperature	Tensile	Yield	Elongation in 2 In.	Reduction of Area
Room	105,000 psi.	55,000 psi.	55%	62%
1800° F.	16,500	—	40	35
1950	10,000	—	45	35

Table II – Stress-Rupture Properties

Temperature	Stress	Time of Rupture	Elongation in 2 In.
1400° F.	21,600 psi.	22.0 hr.	47%
1500	16,600	9.7	61
1600	16,000	9.4	64

The Laboratory Work

Finally, we decided to melt laboratory heats with the basic nickel, chromium, and silicon contents already established. Varying amounts of the three strengthening elements, molybdenum, tungsten, and cobalt, were added singly and in combination, and the resulting alloys were evaluated on the basis of their short-time mechanical properties at high temperatures.

While forging and rolling all heats into 1-in. diameter bars, their hot working properties were closely observed and compared. From the test specimens machined from these bars, we determined that the three strengthening elements gave better results in combination with each other than singly in larger quantities. Therefore, we established a nominal 3% W, 3% Mo, and 3% Co mixture for the alloy. This combination of elements eventually led to the new alloy's trade name. Currently produced as a commercial material, it contains 45% Ni, 25% Cr, 1.25% Si, 3% W, 3% Mo, 3% Co and 0.08% max. C. All harmful residuals are carefully restricted and limited in general to 0.03%. Some mechanical properties are shown in Tables I and II. Stress-rupture values at 100 hr. were:

Temperature	Stress
1350° F.	23,000 psi.
1400	18,500
1450	14,500
1500	10,500
1550	9050
1600	7200

From Laboratory to Production

When the first large heat was produced (in April 1958), it immediately became evident, from the forging difficulties encountered, that we had accomplished our original objective of improved creep and yield properties at high temperatures. From this first heat, we obtained enough alloy to fabricate test equipment for field evaluation.

The alloy was first evaluated for oxidation resistance in the 2200° F. range. When it exhibited excellent properties, several interested companies initiated a series of tests which indicated that the alloy offered considerably improved stress-rupture properties, compression yield strength, tensile yield strength, and stress oxidation resistance. Limited creep data have been determined at 2200° F. with promising results.

Service tests also indicated that it had a very good resistance to thermal fatigue. An unforeseen benefit promoted this property, since the new alloy proved to have a lower coefficient of expansion (8.85×10^{-6} in the 70 to 1800° F. range) than conventional heat resisting alloys.

Hopes for the Future

This new alloy was developed with the expectation that it would be applied where temperatures of 1800° F. or higher were met. For example, it could be used in high-temperature carburizing furnaces and some aircraft and missile brazing processes. However, high-temperature carburizing has not been accepted as extensively as was originally hoped for. Furthermore, the more conventional alloys have performed better than anticipated in inert atmospheres and oxidizing environments encountered at the 2250° F. temperatures used in brazing.

As interest in the new alloy increased, engineers began to test it for baskets, fixtures, and radiant tubes in carbo-nitriding and carburizing furnaces, as well as other conventional applica-

tions. When used below 1800° F. it is not significantly superior in short-time physical properties to more conventional alloys, but its greater creep strength and resistance to thermal shock may make it quite useful. As an example, corrugated carbo-nitriding boxes fabricated from the alloy have lasted three times as long as similar boxes made of the best previously used materials. They still show very little sign of deterioration. In fact, radiant tubes and highly stressed furnace components such as circulating fans and conveyer chains have indicated a comparable increase in life expectancy.

In addition to in-process and standard metallurgical testing for the heat treating industry, the alloy is being tested rather extensively by the glass industry. These tests indicate that the alloy has some excellent properties, including low gas content and low reactivity in contact with molten lime and borosilicate glass at 2400° F. Production tooling has now been in service for well over 1000 hr. with no apparent deterioration of the alloy and no evidence of work contamination.

Some Other Factors

Some practical (if not metallurgical) considerations which should be appealing concern cost and availability. Since the new alloy is produced by conventional arc melting practice in large heats, its cost is less than those alloys requiring vacuum melting. It can be annealed, rolled, formed and welded without highly specialized facilities, and it is readily available. Good, sound ductile welds are obtainable by standard arc welding techniques. Although it is not free machining, neither are the other work hardenable heat resistant alloys.

As is true of all metals, this new alloy should not be considered a "cure all"; it should be specified only after evaluating all of the operating conditions and the properties needed for each individual application. However, we feel that its use can solve many of the problems encountered in fabricating and using equipment built for high temperatures.

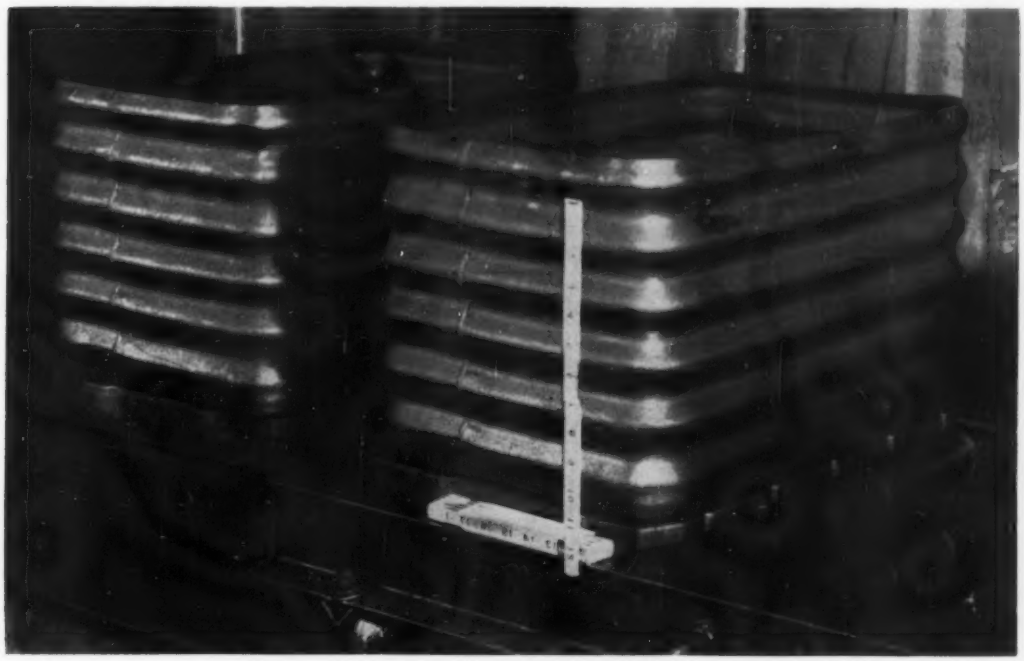
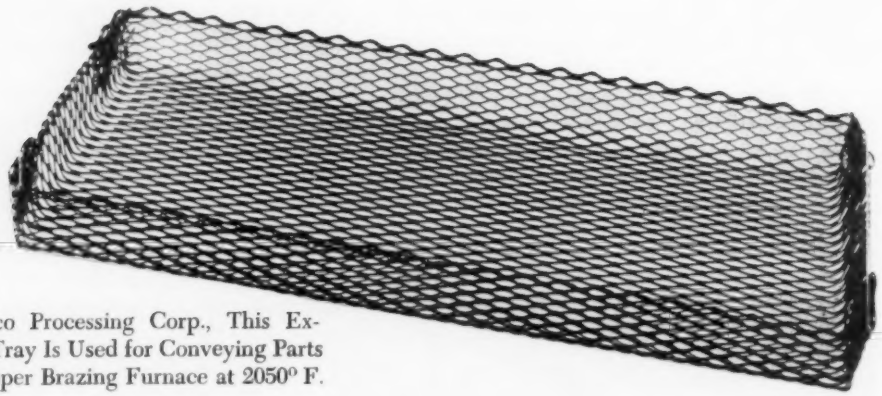


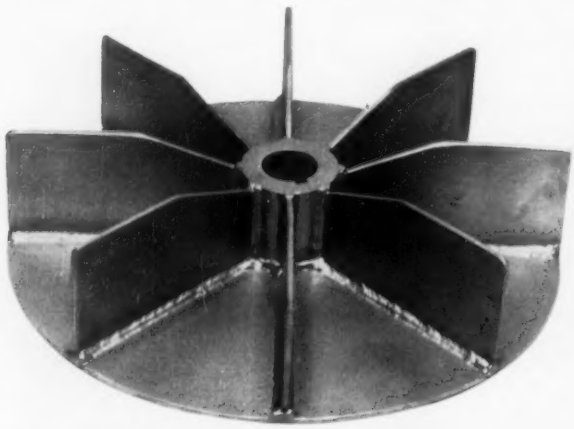
Fig. 1 — Shrouds Used in Atmosphere Furnace at Perfection Tool & Metal Treating Corp. for Hardening, Carbo-Nitriding and Carburizing With Direct Oil Quench. Though in service about 17 months when photographed, there is practically no distortion

More on RA-333 ⟶

Parts Made of RA-333



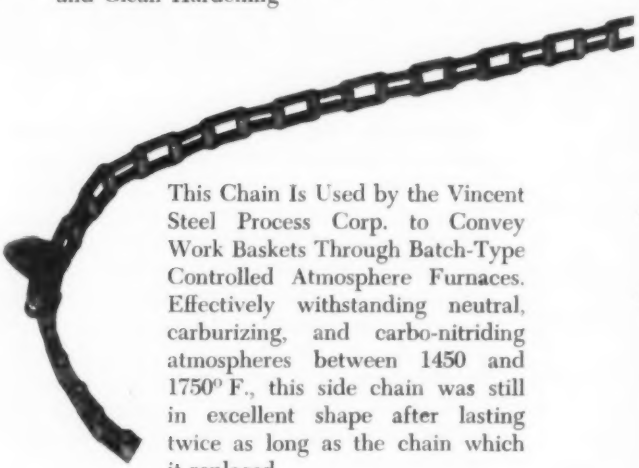
Made by Metco Processing Corp., This Expanded Metal Tray Is Used for Conveying Parts Through a Copper Brazing Furnace at 2050° F.



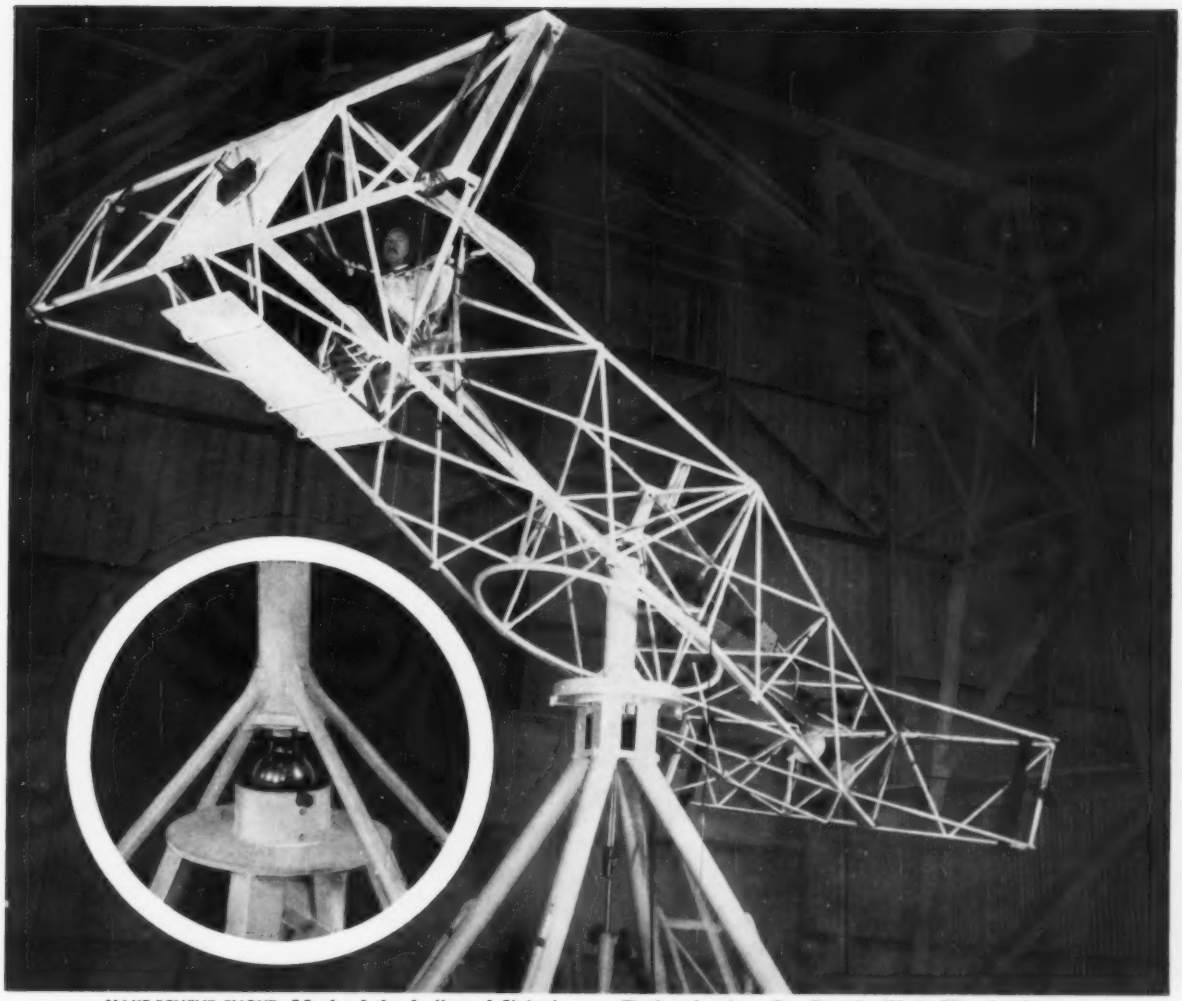
This Circulating Fan Is Used in Carburizing and Carbo-Nitriding Furnaces Which Are Built by Holcroft & Co. Though these fans operate between 1450 and 1740° F. and are highly stressed, the alloy's creep strength is such that deformation is effectively resisted

Constructed by the Aluminum & Architectural Metals Co., This Squirrel Cage Fan Is Used in Batch-Type Furnaces Employing Controlled Atmospheres for Carburizing, Carbo-Nitriding, and Clean Hardening

These Two Items, Which Are Made by the Fab-Alloy Co., Are a Muffle and a Shaker Hearth. They operate in a controlled atmosphere furnace used in hardening small machined parts



This Chain Is Used by the Vincent Steel Process Corp. to Convey Work Baskets Through Batch-Type Controlled Atmosphere Furnaces. Effectively withstanding neutral, carburizing, and carbo-nitriding atmospheres between 1450 and 1750° F., this side chain was still in excellent shape after lasting twice as long as the chain which it replaced



MAKE-BELIEVE FLIGHT—Much of the feeling of flight in a space vehicle is experienced during a ride in this reaction-control simulator, being put through its paces at Boeing Airplane Co., Seattle, Wash. The simulator rides atop the nickel alloy steel ball plated with Nickel in Boeing's ball-and-socket type air bearing.

Space simulator gives the "feel" of flight

Nickel-plated ball of high strength steel supports reaction-control test vehicle

This earthbound space machine is designed to test ways of controlling a vehicle as it pitches, rolls and yaws in the airless reaches of outer space.

In action, the simulator and its payload of test equipment can weigh as much as 5,000 pounds. Yet the necessary sensitivity is achieved by floating the unit on an air-cushion bearing made of a high strength nickel alloy steel ball in its socket.

Imagine this 2½-ton load resting on a ball about the size of a grapefruit! The ball, made of nickel alloy steel heat treated to a tensile strength of 180,000 to 200,000 pounds per square inch, stands up to the load. To provide a hard, smooth surface, the ball is plated with one-thousandth of an inch of Nickel. This uniform surface keeps air leakage in the bearing to a minimum.

Remarkably durable, Nickel and its alloys offer practical solutions to problems of stress, fatigue, abrasion, corrosion or temperature extremes. Used in alloys, in plated coatings or by itself, Nickel helps make possible many new products and processes—and can help improve existing ones—by providing unique combinations of properties.

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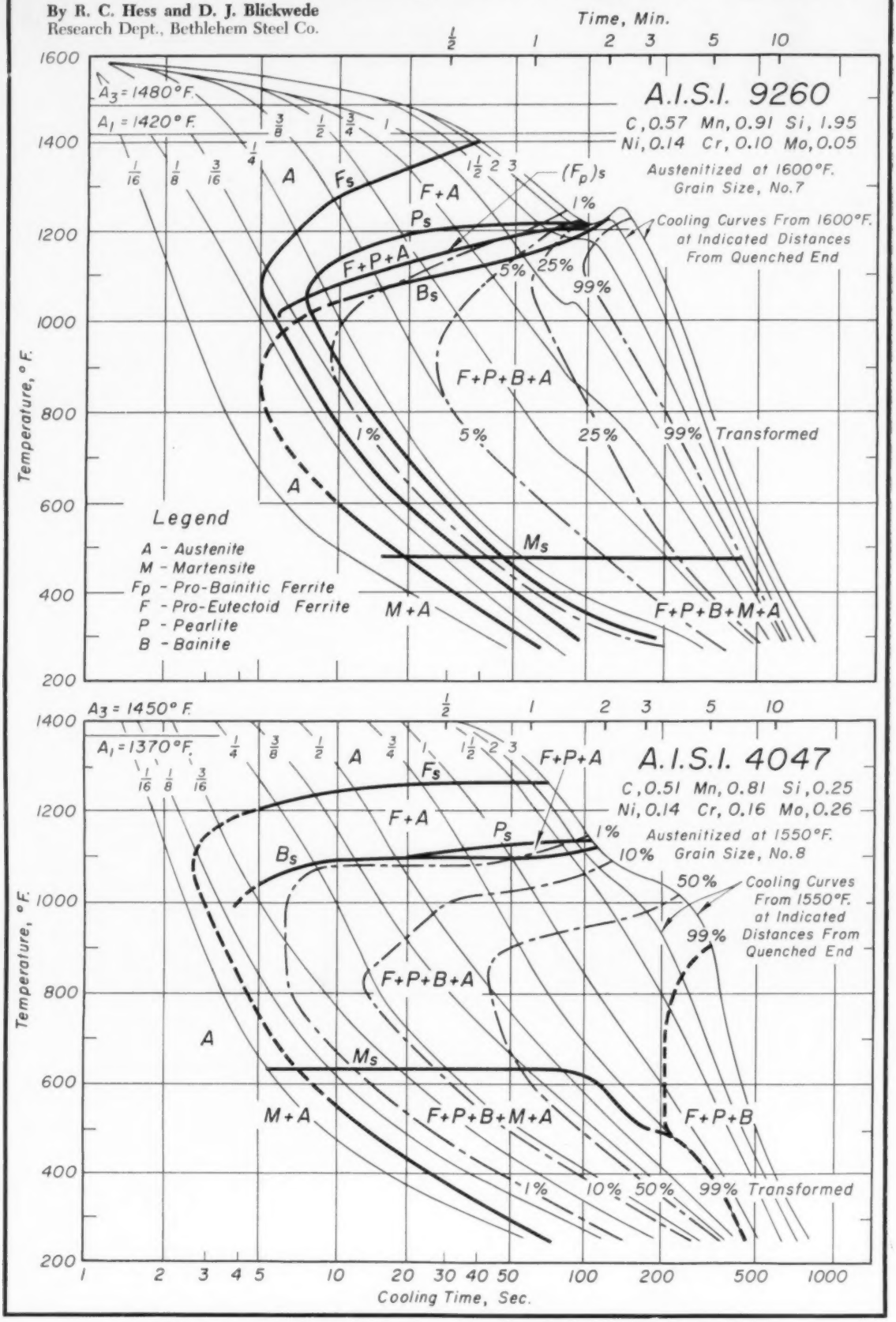
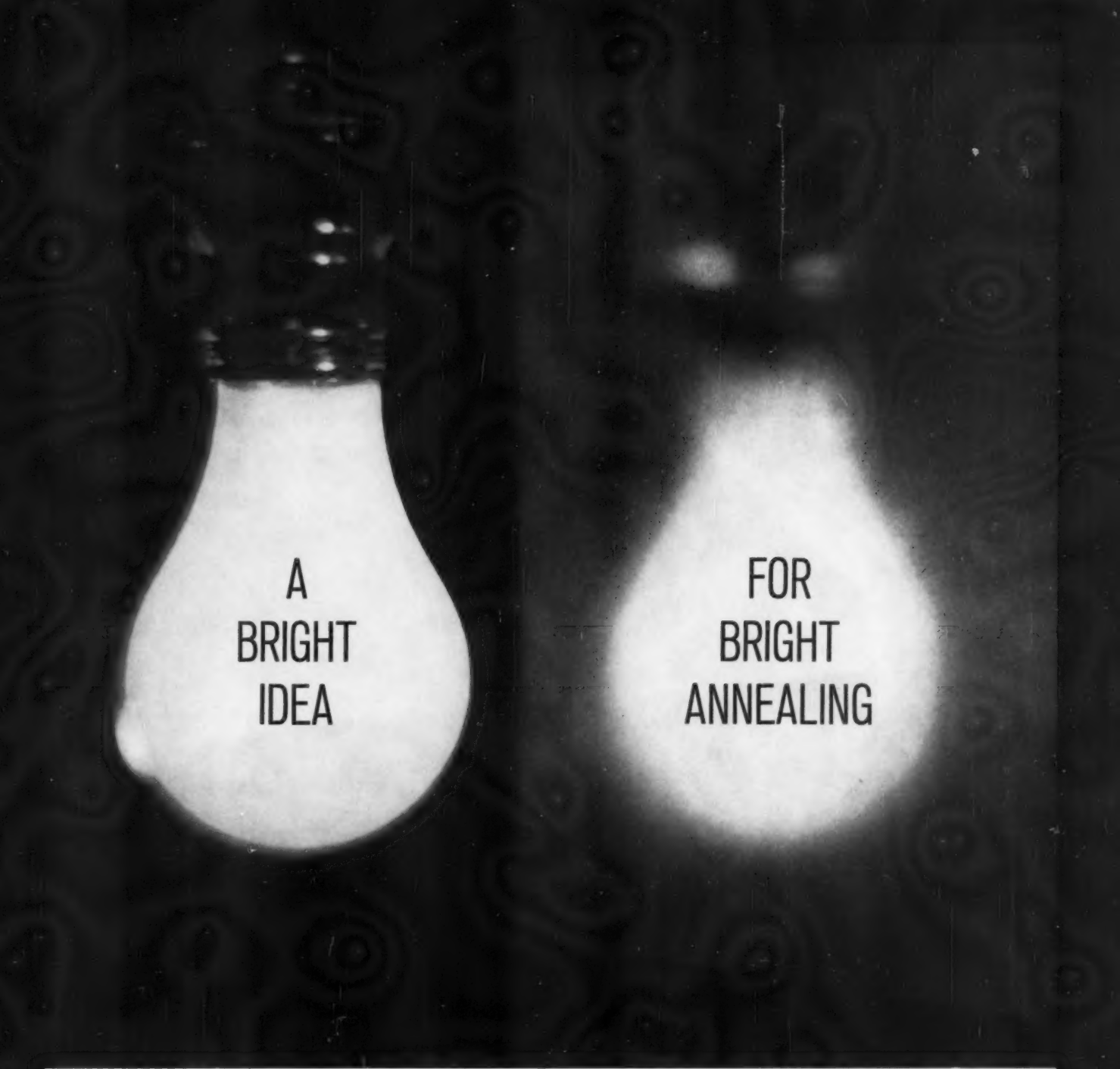
NICKEL MAKES ALLOYS PERFORM BETTER LONGER

Circle 834 on Page 48-B

Cooling Transformation Diagrams for A.I.S.I. 9260 and 4047

By R. C. Hess and D. J. Blickwede
Research Dept., Bethlehem Steel Co.


A.I.S.I. 9260
C, 0.57 Mn, 0.91 Si, 1.95
Ni, 0.14 Cr, 0.10 Mo, 0.05
Austenitized at 1600°F.
Grain Size, No.7
A3 = 1480° F.
A1 = 1420° F.
Time, Min.
Cooling Curves From 1600°F. at Indicated Distances From Quenched End
Temperature, °F.
Legend
A - Austenite
M - Martensite
Fp - Pro-Bainitic Ferrite
F - Pro-Eutectoid Ferrite
P - Pearlite
B - Bainite
A3 = 1450° F.
A1 = 1370° F.
A.I.S.I. 4047
C, 0.51 Mn, 0.81 Si, 0.25
Ni, 0.14 Cr, 0.16 Mo, 0.26
Austenitized at 1550°F.
Grain Size, No.8
Cooling Curves From 1550°F. at Indicated Distances From Quenched End
Cooling Time, Sec.



It takes the right atmosphere to develop brightness in stainless steels during annealing. Dry hydrogen will do it, but a dry N_2-H_2 atmosphere from anhydrous ammonia will do it at less cost. It is the *least* expensive way to supply large volumes of gaseous nitrogen and hydrogen for atmospheres that prevent formation of scale and assure a bright, clean finish.

Allied Chemical Anhydrous Ammonia, dissociated to form a *protective* atmosphere, prevents carburization of metal . . . as a *finish* atmosphere, it prevents discoloration.

It is ideal for: annealing nickel and nickel alloys; electrical steels; beryllium copper; silicon copper; and other copper alloys. Dissociated ammonia is excellent for clean hardening of high carbon and high chrome tool steels . . . for copper brazing of all types of ferrous metals . . . for sintering metal powders.

Our experience with ammonia is unsurpassed by any other producer in this field. Allied Chemical flexibility for shipping ammonia in barge, tankcar, tankwagon, tank truck or cylinders fits every user's needs for saving time and labor.

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MEMBER METAL POWDER mpi INDUSTRIES FEDERATION

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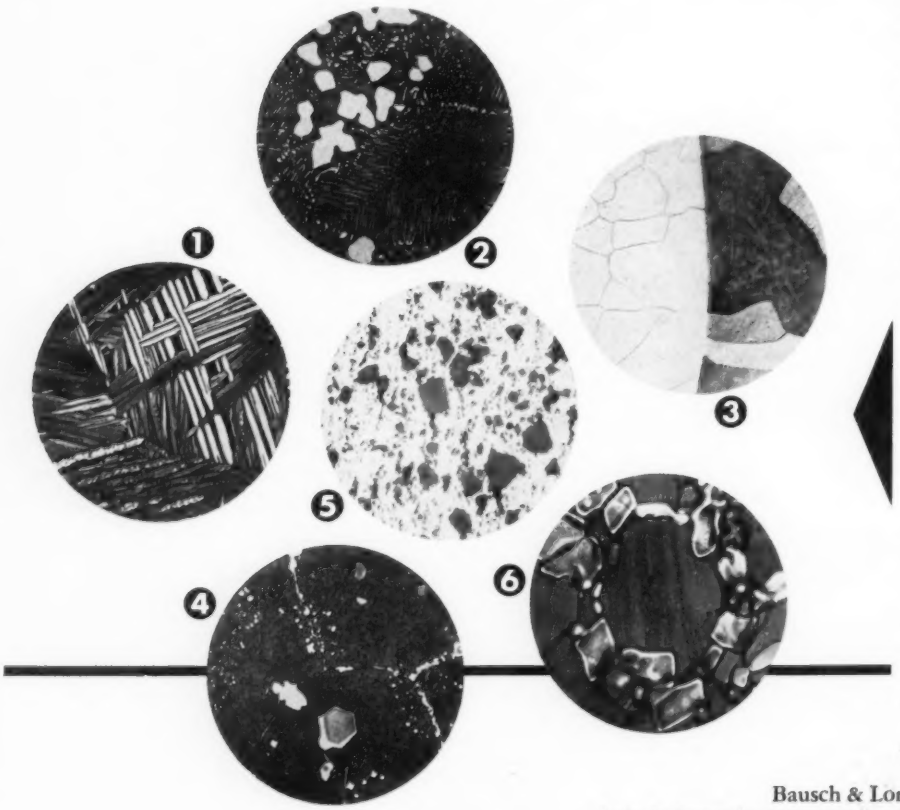
Circle 835 on Page 48-B

Bausch & Lomb salutes:

William C. Coons

. . . Winner of Six Awards in the 1959 A. S. M. Metallographic Exhibit

WINNER OF 3 BLUE RIBBON AND 3 HONORABLE MENTION AWARDS
—Mr. William C. Coons, Senior Research Metallurgist, Nuclear Sciences and Engineering Dept., Research Division, Curtiss-Wright Corp., Quehanna, Pa.



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2. BLUE RIBBON—"Cadmium-antimony alloy showing beta plus gamma eutectic plus primary gamma crystals"
3. BLUE RIBBON—"Molybdenum alloy heliarc welded to tungsten"
4. HONORABLE MENTION—"Udimet 500 polished on new automatic polishing device developed by the Research Division, Curtiss-Wright Corp."
5. HONORABLE MENTION—"UO_2Al cermet fuel element structure"
6. HONORABLE MENTION—"High-density, hot pressed beryllia (BeO)"

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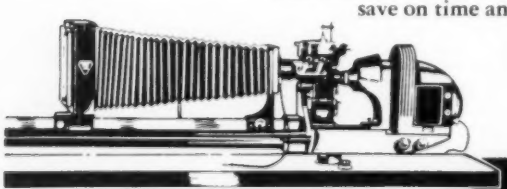

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Heat Treating and Sintering Stainless in an Atmosphere

*By BERNT A. RUEDIGER**

Hydrogen and dissociated ammonia are often used for protective atmospheres when bright annealing or sintering stainless steel parts. This article discusses the characteristics of such atmospheres, and describes the various types of furnaces and gas generators which can be used. (J2k, H15q; SS)

TODAY, THROUGH THE USE of the proper atmosphere, stainless steels can be annealed, brazed, sintered, and, in some instances, fully hardened without oxidation or discoloration. Since these protective atmospheres also eliminate oxidation, there is no surface depletion of chromium, and, consequently, no impairment of the materials' corrosion resistance. Processing costs are reduced (because no subsequent cleaning operations are necessary), and safety hazards and disposal problems associated with acid pickling are also eliminated.

Dry Atmospheres Needed

When a bright surface is required, atmospheres of hydrogen, dissociated ammonia, or vacuum are necessary. To prevent oxidation, the atmosphere, whether it is hydrogen or dissociated ammonia, must be dry. Quantitatively speaking, dew points must be lower than the metal/metal-oxide equilibria of the most active elements in the alloy. For alloys such as stainless steel, where more than one element is present, a dew point lower than that required for the pure metal is needed. For example, while pure chromium will not oxidize at 2000° F. if the dew point is below −20° F., a chromium-nickel stainless steel such as Type 304 requires furnace dew points of at least −30° F. Actually, the best practice for all stainless steels is to maintain a furnace dew point of −40° F. or lower. Stainless steels which contain titanium

*Industrial Heating Dept., General Electric Co., Shelbyville, Ind. This article and H. W. Westeren's article which follows are based on papers presented at a symposium sponsored by the Industrial Heating Equipment Assoc. in Philadelphia during the National Metal Congress and Exposition. Articles in subsequent issues of *Metal Progress* will cover other topics at this symposium including brazing of stainless steel assemblies and heat treatment of stainless flat products, tube and wire. These articles are summaries reflecting the combined thinking, research and development of the member companies of the association.

or aluminum (or both) are troublesome in this respect, particularly since atmosphere inlet dew points lower than −100° F. are not commercially feasible. Thus it would appear that these steels cannot be successfully bright annealed except in vacuum.

However, this is not entirely true since reactions require time. Our tests, in fact, have demonstrated that Type 321 stainless does not oxidize when rapidly processed. Further, A-286 (which contains 2.00% Ti) and PH 15-7 Mo (which contains 0.75 to 1.50% Al) showed only a very light yellow discoloration after similar heat treating. However, where soaking is required (such as in sintering or heat processing heavy sections), stainless which contains aluminum or titanium should be processed in vacuum.

Carburization May Be a Problem

Hydrogen is an excellent carrier gas for carbon. However, since carburization impairs the corrosion resistance of stainless steel, work fixtures and atmosphere must be free of carbonaceous impurities. Recently, we demonstrated the susceptibility of stainless to carburization in pure hydrogen. By annealing Type 321 stainless for 4 hr. in −60° F. dew point hydrogen which contained 200 ppm. methane and 200 ppm. carbon monoxide, we raised the carbon content of the stainless from 0.04 to 0.12%, a threefold increase.

Special care must be taken to avoid carburization when heat processing the extra-low-carbon steels such as Types 304 L and 316 L. In tests which we conducted with a high-purity hydrogen atmosphere (one containing 100 ppm. methane, 200 ppm. carbon monoxide and 20 ppm. carbon dioxide), we found that Type 304 L would be susceptible to carburization at dew points below −50° F. (see Fig. 1). Since the material will also oxidize above −30° F. dew point, processing must be done in the narrow dew-point range of −30 to −50° F.

Dissociated Ammonia May Cause Nitriding

Dissociated ammonia, which is 75% hydrogen and 25% nitrogen, is frequently used in place of hydrogen because of its lower cost. However, there are some problems. Stainless steels are susceptible to nitriding, so heat treaters must be sure that the raw ammonia is thoroughly dissociated. The residual ammonia content in the dissociated gas should be close to equilibrium, as shown in Fig. 2.

Ammonia dissociators operate at temperatures appreciably lower than many annealing or sintering temperatures. Even under optimum conditions, therefore, the ingoing gas contains more residual ammonia than is wanted. As a result, it is best to pass the dissociated atmosphere through an adsorbent (such as synthetic zeolite) before introducing it into the furnace.

Temperatures Are Important

Temperatures and soaking times for treatment and sintering are not fixed. In production annealing tests, the required soak for 35-mil strip was less than 1 sec., an appreciably shorter time than is needed for usual operations. Since 1⅛-in. O.D. bar stock was also fully hardened with soaks of only a few minutes, it seems that it is only necessary to assure that the correct temperature has been reached – unless, of course, massive carbides, severe segregation, or

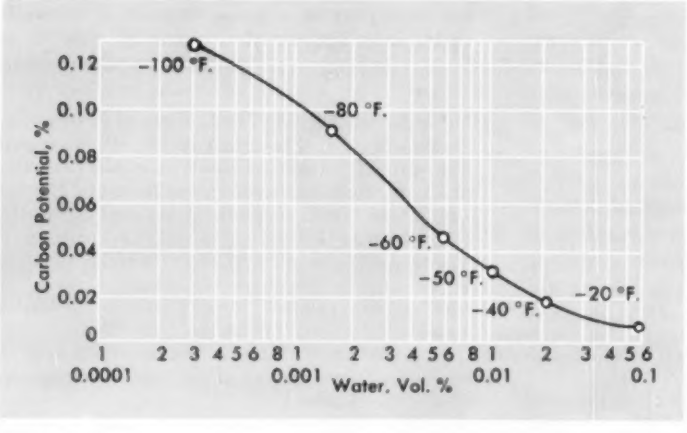


Fig. 1 – Carbon Potential of High-Purity Hydrogen at Several Dew Points. Impurities: 0.02% CO, 0.01% CH_4, and 0.002% CO_2. This curve is useful for adjusting furnaces because stainless steels are prone to carburize at low dew points

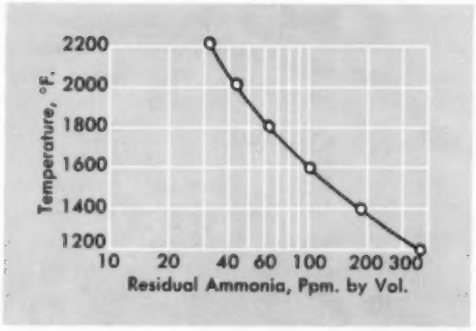


Fig. 2 – Ammonia Equilibria for a Range of Temperatures; Pressure, 1 Atm. To prevent nitrides from forming (when annealing stainless steels in dissociated ammonia), the ammonia content should be kept close to equilibrium

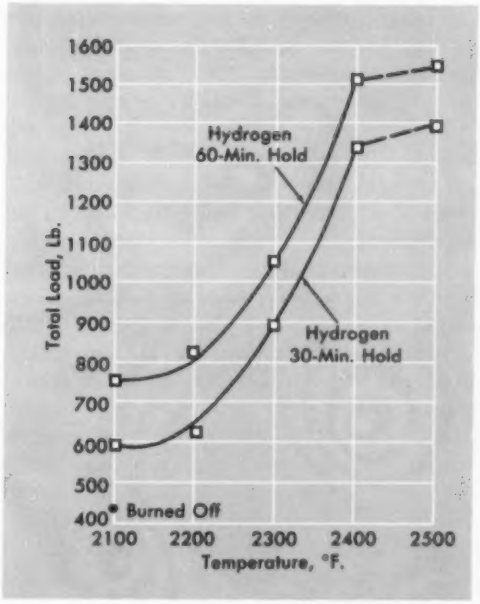


Fig. 3 – Improvement in Ductility and Strength Which Occurs With Higher Sintering Temperatures. Tests were run on Type 302 stainless steels, and the dew point was −40° F. At the top two sintering temperatures the tests did not fracture

grain growth are factors. The amount of prior cold work also should be taken into account, because austenitic alloys that have been severely cold worked will recrystallize more rapidly and at lower temperatures.

Sintering, which requires the diffusion of metallic atoms between adjacent particles, necessitates rather long times. High sintering temperatures are recommended since they produce a more ductile product than lower temperatures at equivalent times. A recent experiment of ours proved this. As Fig. 3 shows, the load-to-fracture (of sintered nuts of Type 302 stainless) rose with the sintering temperature. In fact, no fracture occurred in parts sintered in hydrogen at 2500° F.

Two Other Factors

In commercial practice, a lubricant (stearic acid, zinc stearate or lithium stearate, for example) is usually used in compacting stainless powders. Though these lubricants generally improve the green compact density and increase die life, there are some drawbacks. Stearates are carbonaceous compounds which, as mentioned previously, are undesirable. Also lithium and zinc are troublesome because they condense in the cooler portions of the furnace. This makes it necessary to clean the furnace quite often. Best practice: Burn off or volatilize these lubricants in separate equipment before sintering. Separate burn-off or volatilization also reduces cracking during sintering, because the raw compacts are stress-relieved.

Most of the austenitic stainless steels are susceptible to carbide precipitation. This phenomenon, which drastically reduces the corrosion resistance of the material, occurs when the steels are cooled slowly through or held in the 1400 to 900° F. range. Rapid cooling is therefore recommended. With the new industrial furnaces available today, bright hardening of stainless steel is practical. In fact, section sizes with thicknesses up to 1⅝ in. O.D. have been fully hardened without oxidation or the slightest discoloration. Precipitated carbide, however, does not interfere with forming. Consequently, in-process anneals can be slow; rapid cooling is needed only after the final anneal to prevent this carbide precipitation.

Gas Generating Equipment

High-purity hydrogen can be purchased in bottles, tank trucks, or generated (up to 99.999% purity) from ammonia or natural gas. Atmospheres produced by the dissociation of liquid ammonia in an iron or nickel catalyst bed can have a dew point of −60° F. and residual ammonia contents of less than 100 ppm.

As discussed previously, the dew point in the furnace must be −40° F. or lower to insure bright work. To maintain such low dew points

the ingoing gas must be appreciably dryer, preferably −80 to −100° F. Dissociated ammonia should have a minimum residual ammonia content to prevent the possibility of nitriding.

To remove both water and residual ammonia, regenerative dryers – the active agent is either activated alumina or molecular sieve adsorbents – are available. The latter adsorbent is preferred because it provides a lower dew point. For best results, the "bleed"* system of reactivation is recommended. With such equipment, outlet dew points of hydrogen and dissociated ammonia are −90 to −100° F., and residual ammonia contents will drop from 500 ppm. to 5 ppm. or less.

When large quantities of gas must be dried, a split bed dryer is economically more advantageous. A split bed unit has both activated alumina and molecular sieve adsorbents; the first removes the bulk of the water while final drying is accomplished by the latter.

Dryers also remove carbonaceous impurities such as methane, carbon dioxide and carbon monoxide. Synthetic zeolite adsorbents, however, will pass these gases as they become saturated with water. Thus, an oversized dryer is preferred if these contaminants are present.

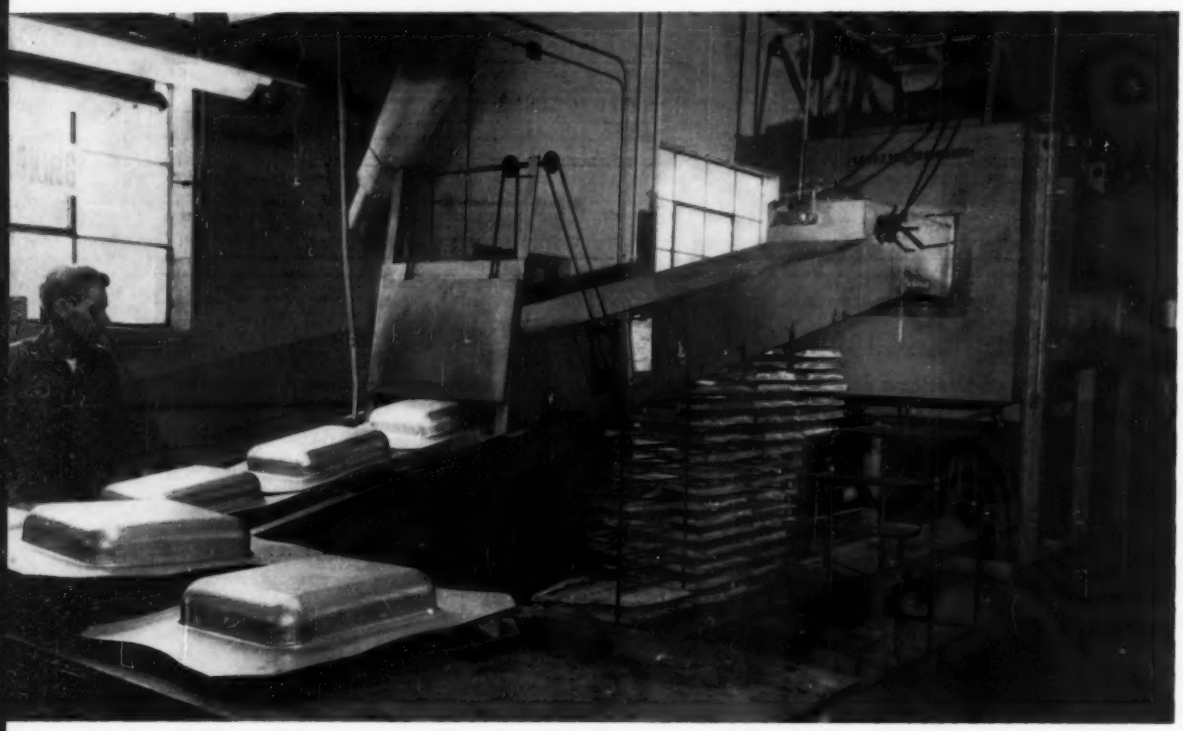
Furnaces Are Versatile

For bright heat processing, equipment is available for both batch and continuous production. Although bell, horizontal mesh belt and roller hearth furnaces can be used, the box, hump-type mesh belt, and pusher are more common.

Box furnaces which are lined with a high-purity refractory (completely inert to hydrogen or dissociated ammonia) can operate to 3200° F. High-temperature furnaces – those operating above 2100° F. – have molybdenum resistance elements. A water jacket chamber provides uniform and rapid cooling. Although available in a variety of sizes, the most common furnaces

*Normally, the adsorbent is reactivated by heating. In the bleed system, some atmosphere is also passed through the saturated adsorbent.

Fig. 4 – Hump-Type Electric Furnace Is Used for Bright Annealing Kitchen Sinks (at Hi-Temp, Inc.) Made of 18-8 Stainless. A mesh belt carries the sinks continuously through the hydrogen atmosphere



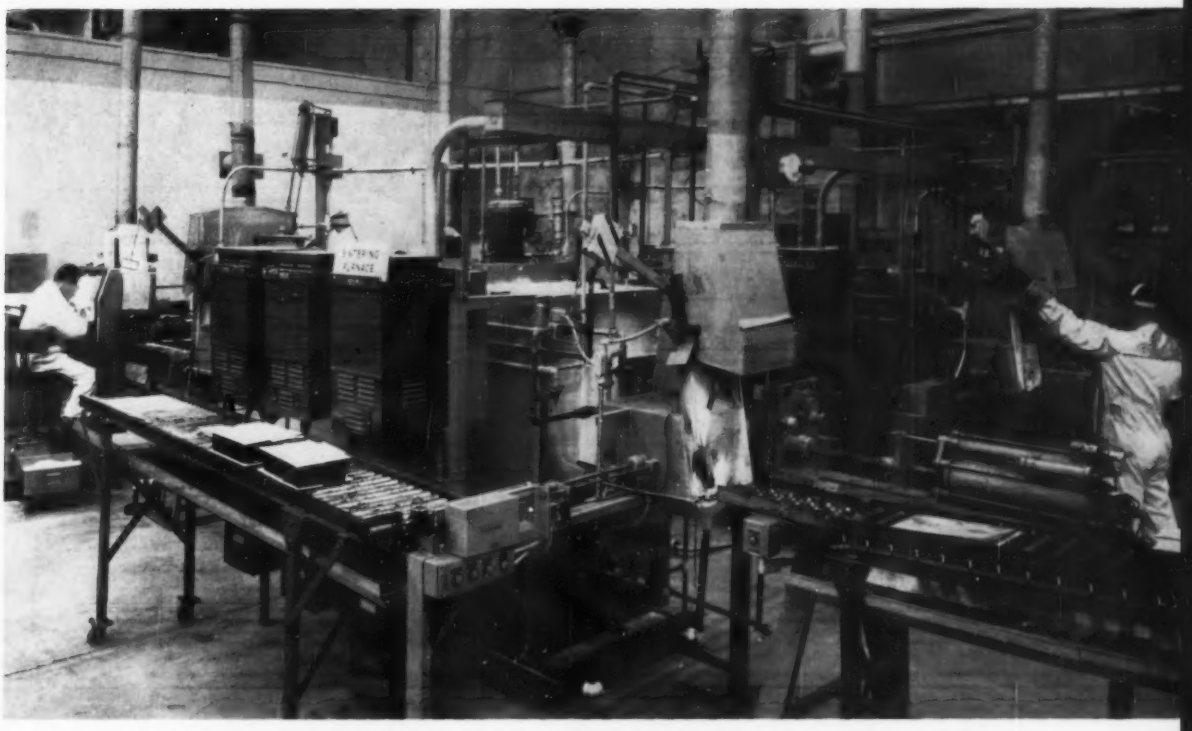


Fig. 5 – Operator at Right Charges Pusher-Type Sintering Furnace While Operator at Left Loads Pellets Into Molybdenum Boats for Subsequent Sintering

have door openings to 24 in. wide by 8 in. high. Many such furnaces are now being used for applications such as bright annealing of turbine buckets, cutlery and other small components.

Figure 4 illustrates a hump-type furnace which consists of an inclined charge chamber, horizontal heating chamber and cooling chamber, and declined cooling chamber. The pieces – in this instance, kitchen sinks – move through the furnace on a woven alloy belt. Lined with high-purity refractory, this furnace chamber is heated by molybdenum elements above and below the hearth level. Furnaces operating to 2200° F. are available.

This type of furnace is easy to load and unload, and has a high production capacity. Also, less atmosphere is used in hump-type equipment because of the "self-sealing" effect of the lighter-than-air hydrogen in the inclined charge and declined cooling chambers.

As Fig. 5 shows, the pusher furnace is horizontal equipment. Being available for 3200° F. operation, heating and cooling chamber construction are similar to the box furnaces. The furnace is continuous in that work is conveyed on trays that follow one another through the furnace.

The pusher furnace is ideal for sintering since it permits the use of higher temperatures than mesh belt or other types of continuous furnaces. In general sintering practice, the work enters the furnace through a purging chamber and goes through separate volatilization, sintering and cooling sections. Finally, the cooled work is removed from the furnace through a purging chamber.

The most recent advance in bright heat processing is the vertical tower furnace, a tall, narrow unit which anneals stainless steel strip in one downward pass. The heating chamber, rated 2300° F., is lined with high-purity alumina and heated by molybdenum resistance elements. Jet coolers provide rapid cooling to room temperature. Dew points of −60° F. are held continuously with hydrogen consumption of only 1000 to 2000 cfh. A typical production furnace will anneal 6000 to 8000 lb. per hr. of strip 0.005 to 0.060 in. thick and 24 in. wide.

Vacuum Furnaces Are Versatile

*By H. W. WESTEREN**

For tricky heat treating applications – brazing stainless steel parts, for example – vacuum "atmospheres" can be very useful. This article details the characteristics and applications of vacuum heat treatments. (J2k, 1-73)

THE "VACUUM ATMOSPHERE", though a relative newcomer to the heat treating scene, is being used in an increasing number of metallurgical applications. Among them are hardening beryllium copper, tempering high speed steels, and silver brazing nonferrous metals – to name a few. Alloys containing aluminum, titanium, columbium, or tantalum can be very successfully kept free of oxidation and absorbed gases.

Before we discuss some of the applications, however, it might be well to describe a vacuum atmosphere. Actually, it is any environment below atmospheric pressure (760 mm. Hg). As you can appreciate, there are always residual gases in an evacuated chamber regardless of the degree of vacuum. Further, the characteristics of the material being processed affect the degree of low pressure desired. A very high vacuum or low pressure thus does not necessarily produce good work, the proper ratio of temperature, atmosphere and cycle time being the only assurance of successful processing.

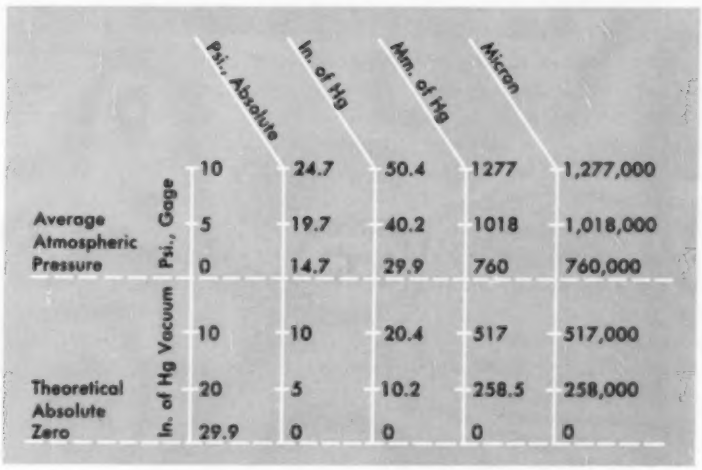
Here, a word about "degree of vacuum" is needed. Pressures in vacuum atmospheres are measured either in millimeters of mercury or in microns. Stainless steels are usually processed between 1/10 of a micron and 1 micron of pressure, while other work may be done at 1/1000 of a micron or up to 100 microns, or at whatever degree of pressure is required for satisfactory results. The chart in Fig. 1 is a convenient way to convert the various vacuum measuring systems one into the other.

To determine the correct operating pressure and procedure during heat treating, we have to consider the oxidation characteristics of the material being processed. In other words, how do we prevent oxides from forming, or remove those already present? Since oxides at a given temperature become unstable at different pressures, we must decide which pressure will produce the best results.

Chamber tightness is also important. If the furnace chamber is not constructed and maintained to minimize leakage, it is impossible to take full advantage of the pumping system. A poorly constructed chamber with a high leak rate will need a high pumping capacity to obtain a certain pressure. It cannot produce the results of a tight chamber (in which a lower pumping capacity answers the purpose) since infiltrating gases passing through the chamber would accelerate oxidation.

*Assistant Research Director, C. I. Hayes, Inc., Cranston, R.I.

Fig. 1 – Conversion Chart for Atmospheric Pressures



The vacuum chamber should be kept clean. Furthermore, all the parts should be cleaned and degreased before heat treatment since any oils, greases or solvents will produce undesirable gases during heat treatment. They may also leave detrimental residues on the parts.

What About Outgassing?

All materials contain gases which are released when heated to given temperatures under low pressures. Therefore, an adequate pumping system is needed to remove these liberated gases and maintain the desired pressure during the heat treating cycle. The rate of outgassing is largely dependent on the rate of heating. Even though a furnace is being operated continuously, gases are reabsorbed by the furnace components when they are exposed to atmospheric pressures. The time of this exposure will determine the amount of gas absorbed. Therefore, it is important to maintain the "vacuum atmosphere" in the chamber whenever possible.

Another important factor is sublimation – the transformation of a material from the solid state directly to the gaseous state. This phenomenon is more frequently encountered when heat treating in low-pressure atmosphere because it occurs at lower temperatures with reduced pressures. In fact, in some stainless steel processes, sublimation occurs at oxidizing temperatures. Therefore, it is necessary, when

Table I – Typical Vacuum Metallurgical Processes

Material	Process	Pressure	Temperature Range
Beryllium copper	Hardening	1/10th micron	650° F.
Stainless steel	Hardening	1/10th micron	650
High speed steels	Tempering	1/10 to 1/100	1000
Ni-Span C	Hardening	1/100	1250
Nonferrous materials	Silver brazing	1/10	1500 to 1800
Stainless steel	Annealing	Less than micron	1800
Stainless steel	Hardening	Below micron	1850
Stainless steel and other ferrous metals	Copper brazing	1/10 to 10	2000
Stainless steel	Nickel brazing	Below micron	2000 to 2300
Stainless steel	Sintering	10 to 50	2200 to 2400
High speed steels	Hardening	Micron	2300
Tantalum	Annealing	1/100	2600 up
Tungsten carbides	Sintering	50 to 100	2650
Refractory metals	Platinum brazing	Micron	3200

using vacuum, to closely analyze both the oxidation and vapor pressure characteristics of the material being heat treated, so as to determine the proper temperature cycle required to process the part. In most instances, the process must tread the straight and narrow band between oxidation and sublimation temperatures. In some stainless steel processes, for example, it is necessary to heat and cool the work rapidly at controlled rates; this can be done in available vacuum equipment with excellent results by moving the work into an adjacent cooling section.

Since cycle time, outgassing and desired pressure all affect the pumping system's design, the process for the work should be properly analyzed to determine the type and capacity of pumping equipment to be used.

Fig. 2 – Brazed Joint in a Jet Engine Starter Component Made From a Type 300 Series Stainless Steel. It was brazed at 2175° F. (brazing alloy – A.M.S. 4775) under a vacuum of less than one micron. 100 ×

Typical Vacuum Processes

All but one of the various processes listed in Table I necessitate the evacuation of the chamber to a given pressure which is maintained throughout the entire heat treat cycle. The exception is copper brazing of stainless steel. To remove oxides from the steel and prevent copper from subliming, the chamber is first evacuated to below 1 micron pressure. Preheating to 1750° F. removes oxides from the work. Then, the chamber is back-filled with argon or helium to a pressure of 10 microns, the part is heated to the flow point of the copper, and the temperature is lowered under high vacuum.

A Suggested Economy

When nickel brazing stainless steel, a considerable reduction in the required pumping capacity can be realized by following this procedure: Load the furnace, evacuate it down to 100 microns and preheat the parts to 1300° F. Between 700 and 900° F., nickel braze resin binders become gaseous and can be evacuated. (By evacuating this gas at the 100-micron range, instead of below a micron, more gas can be removed with a given pumping capacity.) After outgassing, evacuate the chamber to below a micron and raise the temperature to approximately 1750° F. As rapidly as possible, bring the stainless steel to the flow point of the braze metal and then cool in vacuum atmosphere to prevent oxidation.

As we have said, there are many factors to be considered when selecting a vacuum furnace: Temperatures, pressures, heat treat cycle, size of parts to be heat treated, necessary arrangement of parts during heating process, rate of production, quality and type of results desired, types of controls, and instrumentation.

For specific processes, the user may desire the "hot wall" type of vacuum equipment which consists of a vacuum-tight retort heated by conventional furnace equipment, or he may want the double evacuated "hot wall" type which can operate at higher temperatures because the effect of atmospheric pressure is removed from the vacuum retort.

On the other hand a "cold wall" type furnace may be the choice. This type has become popular because of its flexibility – its ability to operate at higher temperatures and lower pres-

Fig. 3. This Type 440C Stainless Steel Was Heat Treated in a Vacuum. 500 ×

sures (than the hot wall type), its speed of heating and cooling, its faster cycling, and its adaptability to almost any size of chamber. Equipment can be arranged so that the processing furnace is horizontal or vertical, or it can incorporate adjacent cooling chambers for quenching or cooling work. It can also be equipped with mechanized conveyers to move work through various cycles, or it can be equipped with vestibules to admit and remove work from the atmosphere chamber without changing the environment in regard to temperature and pressure.

As for versatility, one company in the aircraft field reports that a furnace purchased only for nickel brazing of stainless steels is now hardening high speed steels, brazing complex stainless steels, nickel-alloy plated (which are hardened and tempered in a single operation), and outgassing Hastelloy W parts and welding rods which are subsequently welded into an assembly. Figure 2 illustrates a typical brazed joint.

Another company, in the electronics field, purchased a vacuum furnace for hardening beryllium copper. They now also use the furnace for hardening Ni-Span-C, and for annealing stainless steel (see Fig. 3). Vacuum equipment has also been used for brazing heat exchanger tubes made of stainless steel, copper brazing and hardening of stainless steel parts, and also for general heat treat work.

One company realized a great saving when a quantity of stainless steel parts – long shafts with a gear assembly, copper brazed to the end – had to be remachined or remade because of a change in specifications. They were able to anneal the parts in "vacuum atmosphere" and thus re-machine them, and then harden and temper them in vacuum with excellent results. Furthermore, the parts processed in this equipment are truly "job shop" in variety.

Another vacuum furnace, originally built for brazing and annealing stainless, was later used for annealing tantalum above 2500° F., and has now been changed for firing ceramic semiconductor wafers.

In conclusion, we can say that the economics of industrial heat treating are being proved every day in many ways, through the versatility and flexibility of vacuum processing. Of course, vacuum has its limitations. Other types of atmospheres will continue to be used where they are most practical and economical. However, it should be emphasized that the people who can best evaluate this promising new medium – the "vacuum atmosphere" – are the furnace manufacturers who are able to bring to each problem a large fund of practical metallurgical knowledge. It may be that the vacuum is what you need to solve your particular heat treating problem.

A Biographical Appreciation . . .

Peter Payson
Assistant Director of Research
Crucible Steel Co. of America

"MANY OF THE REAL BREAKTHROUGHS in technology occur not by design but by accident – and the delightful word for this is serendipity." This remark, made during a recent talk by Peter Payson at a Crucible departmental meeting, is typical of "Pete", as his many friends throughout the steel industry call him. He would never acknowledge that his own deep knowledge and wide experience were largely responsible for the 36 patents he holds today. Instead, he claims that many of them are due to a "happy accident", that is to say, an unusual finding in a conventional experiment which ultimately led to an important invention. Actually, as every researcher knows, a great many experiments have unexpected results. Subsequent developments then depend entirely on the general competence – or lack of it – of the experimenter. Certainly, Peter Payson has competence to spare.

How he came by it makes a fascinating story. Born in Brooklyn near the turn of the century, Pete spent his early years in a neighborhood which today would be classed euphemistically as a "blighted area". Even though, according to him, his hard-working parents preferred that he become a doctor or a business man, his grades in mathematics, physics and chemistry were such that he decided upon engineering. (Was there serendipity here?) At any rate, he entered Columbia with that goal in mind. After six years of subway commuting between Brooklyn and Manhattan, he left that school with a degree in metallurgical engineering. Shortly thereafter, he started working for Crucible Steel Co., where he has been ever since.

Beginning as a metallurgist at the Halcomb Works in Syracuse, N.Y., he early adopted the Crucible tradition of brilliant one-man research efforts which started with J. A. Mathews' invention of 18-4-1 toolsteel in 1904. As manager of the Research Laboratory in Harrison, N.J., between 1929 and 1955, he worked steadily and productively in many fields of metallurgy; stainless steels, high-strength alloy steels, toolsteels, and superalloys are just a few examples.

His first patent – it concerns the valve steel dubbed XCR – came in that period; it was, he says, entirely due to serendipity. It seems that he was asked to suggest an annealing treatment for a new type of high-chromium, acid resistant steel. When he was told that overnight heating at 1400° F. made the experimental steel *hard* instead of soft, he decided to do some experimenting of his own, and much to his surprise, this hardening had actually occurred – moreover, it was reproducible. To make a long story short, after much thought and work, he devised both the optimum analysis and treatment needed to make this alloy a superlative steel for automotive valves, one that has been in use for many years.

Another important invention Pete modestly attributes to serendipity concerns the cycle annealing of steel, probably his best known contribution to steel treating. It all began back in 1937 when he was asked to prepare a talk for plant personnel on the then unfamiliar subject of isothermal transformation. Though this speech, which was based on U. S. Steel publications, was well received at the Harrison laboratory, the production men at Syracuse challenged him to reproduce these laboratory results on full-sized heats. Accepting this dare, he found that austenite can be transformed directly to a spheroidal structure. This investigation eventually led to two patents, two publications and sizable savings in cost and time throughout the steel industry.

There is not room to detail all of Peter Payson's accomplishments for Crucible – even to name those that are the most important would take time. One which certainly should be mentioned is "HY-Tuf", the high-silicon steel that could be heat treated to 230,000 psi. – this steel led to the new concept of ultra high strength steels now used so widely in today's aircraft and missiles.

Not all of his time has been spent in the laboratory, however. Being a firm believer in spreading the word about metallurgy, he put in many long evening hours from 1941 to 1955 teaching graduate courses at Stevens Institute of Technology. Also, much more time was spent in giving talks on heat treatment to many A.S.M. chapters throughout the country.

All these years of experience were put into use in preparing for what he considers his greatest honor – the opportunity to deliver the Campbell Memorial Lecture. In that talk, the highlight of the 1958 Convention, he outlined his thoughts on "Tempered Alloy Martensites", concluding modestly with a long list of questions still to be answered about toolsteels. Today, as assistant director of research for Crucible's new Pittsburgh laboratory, Pete spends much of his time writing a comprehensive volume on toolsteels. Cared for by his devoted wife, Beatrice, he hopes to finish it by the end of the year. Good luck, Pete!

Report From Yugoslavia

Modern Plant Produces Oxygen-Free Copper

*By DRAGOSLAV JANICIJEVIC**

The entire output of oxygen-free copper at this Yugoslav plant is cast as wire bars in a continuous casting machine. Contamination of molten cathode copper is prevented by melting and holding the metal in enclosed induction furnaces and by protecting it with an atmosphere composed of carbon monoxide and nitrogen. (C5q; Cu-a)

ALTHOUGH FIRST ATTEMPTS in producing oxygen-free copper were made as early as 1919 in the casting shop of Scovill Mfg. Co., Waterbury, Conn., it was not until 1931 that production quantities reached the metals market. Since then the United States Metals Refining Co., Carteret, N.J., has produced oxygen-free copper under the trademark OFHC. Some 20 years ago a company in Finland became the second source of oxygen-free copper. Until 1955, when Fabrika Kablova Svetozarevo in Yugoslavia began operating a new plant built by Ajax Engineering Corp. (now Ajax Magnethermic Corp.), Trenton, N.J., these were the only two producers.

When Fabrika Kablova Svetozarevo was planned, it was decided to depart from conventional practices and cast wire bars at the cable plant rather than at the electrolytic refinery. Several melting and casting methods such as stationary or rotary reverberatory furnaces and horizontal casting wheels were considered. Finally, it was decided to make oxygen-free copper using induction melting and holding furnaces. Today, the Fabrika Kablova Svetozarevo is the only wire and cable plant in the world which uses this kind of copper in all its products. It is also significant that 50% of the entire output of cathode copper in Yugoslavia is directed toward production of oxygen-free copper.

*Chief Metallurgist, Fabrika Kablova Svetozarevo, Svetozarevo, Yugoslavia.

What Is Oxygen-Free Copper?

Oxygen-free copper is produced in equipment which protects the molten metal (remelted cathode copper) from air during the entire melting and casting process. Oxygen-free copper is not deoxidized copper in which the oxygen is tied up as an oxide of phosphorus, lithium, or some other metal. Instead, selected cathode copper is converted directly into the desired cast shape under conditions of strict control which prevent contamination. This procedure assures a metal of high quality with a copper content ranging from 99.95 to 99.99%.

Since it contains few impurities, oxygen-free copper has characteristics such as excellent electrical conductivity and formability which are close to that of pure copper. Its ductility is practically unchanged by cold deformation. Thus it can undergo successive drawings with-

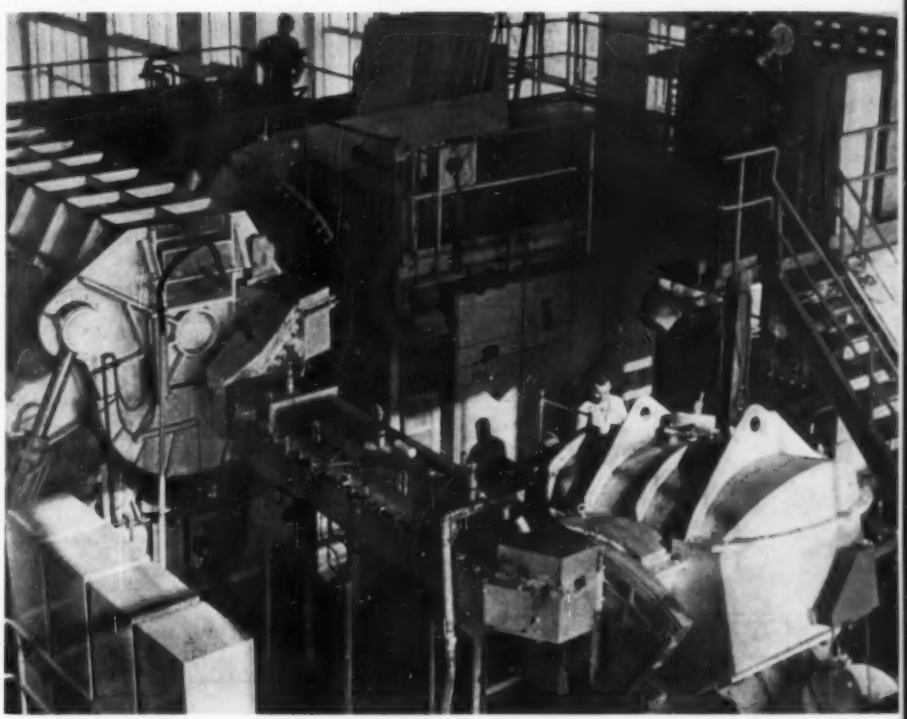


Fig. 1 – Casting Platform at Fabrika Kablova Svetozareva, Yugoslavia. Copper cathodes (top center) enter melting furnace (left). Liquid metal flows through heated launder (center) to pouring furnace (lower right), then to continuous casting machine. Enclosed melting and pouring furnaces and launder contain protective atmospheres which prevent oxidation. Contamination is also prevented by using induction furnaces

out intermediate annealing. Combined with high electrical conductivity, these properties have made oxygen-free copper an excellent metal for cables and conductors.

Oxygen-free copper is immune to embrittlement caused by exposure to a hydrogen-bearing atmosphere at elevated temperatures. When copper which contains oxides is heated in the presence of hydrogen, it is weakened considerably because the oxides are reduced and water vapor forms at grain boundaries. Since oxygen-free copper contains little or no oxide, this reaction does not occur. The metal is, therefore, well suited to applications in electronics and to welding, bright annealing, and other operations where it comes in contact with hot hydrogen.

Another feature of oxygen-free copper of particular advantage to the electronics industry is that outgassing is not a problem.

Melting and Casting Procedure

As pointed out, oxygen-free copper owes its unique properties to procedures which protect the metal during melting and casting. Copper cathodes produced by electrolytic refining must be remelted and cast into commercially useful shapes. Today about 72% of the world's cathode copper production is remelted in reverberatory furnaces. Unfortunately, such a procedure results in contamination of the high-purity copper and necessitates another fire-refining step.

Because of this disadvantage, cathode copper at Fabrika Kablova is melted down in induction furnaces (Fig. 1). Contamination is also minimized by thoroughly washing the cathodes at the electrolytic tank house. They are given no other special cleaning treatment before being charged.

Figure 2 is a schematic diagram explaining the production of oxygen-free copper at the Fabrika Kablova casting shop. The starting material consists of copper cathodes containing at least 99.96% copper and having a fine-grained structure. As described earlier, these are washed to remove sulphates and other impurities stemming from the electrolytic process and are charged into the melting furnace. The metal flows continuously from this furnace down a spout launder and through an electrically heated launder into the pouring furnace. From the pouring furnace, the molten copper is sent into the bottomless chill mold, a Junghans-Rossi continuous-casting machine, in which the metal solidifies into a wire bar. Sprayers located in a chamber beneath the chill mold cool the wire bar to room temperature. From this

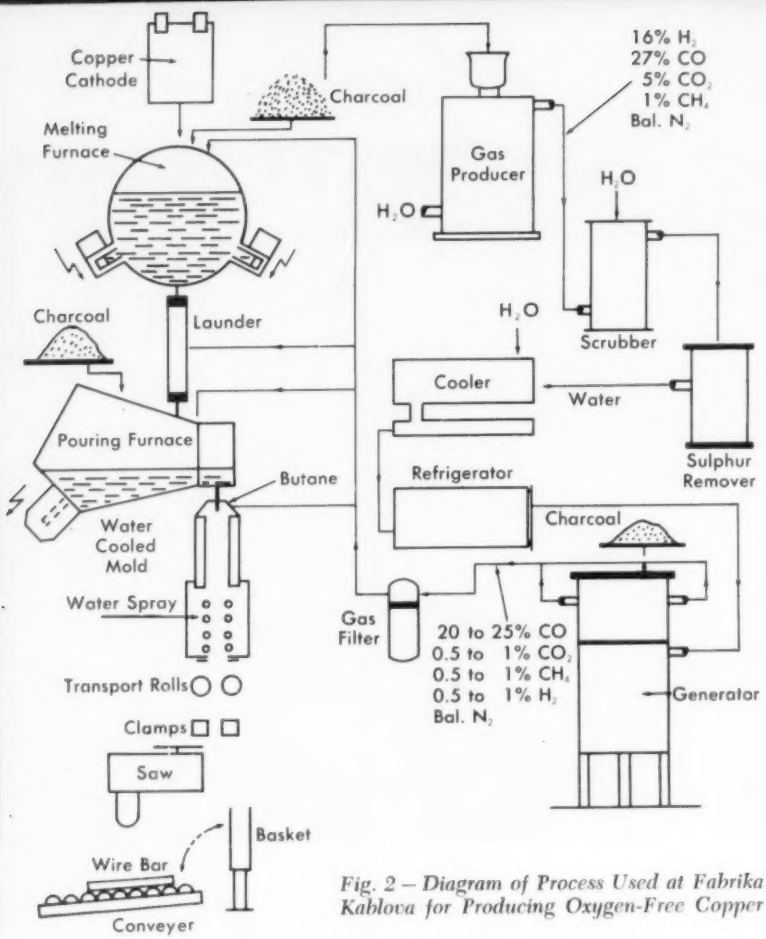


Fig. 2 – Diagram of Process Used at Fabrika Kablova for Producing Oxygen-Free Copper

chamber the wire bar passes through a rubber wiping box to transport rolls which draw it down at a constant speed toward a saw. The wire bar is automatically cut to desired length by a mechanism which follows its downward travel.

The metal in both furnaces is covered with a layer of charcoal. The protective gas, made in a gas producer, passes through a scrubber, a sulphur remover, a gas converter for complete combustion of the producer gas and a refrigerator for moisture removal. From here it goes to another generator where the gas is reduced in a retort by red-hot charcoal. The reduced gas is filtered and passes to the hood above the chill mold and into the melting furnaces, the launder, and the pouring furnace, thus preventing contact between the molten metal and air.

The melting furnace consists of a hexagonal welded steel drum with openings at both ends for cleaning the furnace and charging charcoal. Cathodes are charged through a door at the center of the upper half of the drum, slightly above the horizontal plane passing through its horizontal axis. A pair of openings is provided for the inductors on each side of the lower half of the drum.

At one end of the furnace a launder is arranged in such a manner that the discharge opening is located at the center of rotation of the furnace, slightly below its center. The furnace is mounted on a frame and rolls and may be inclined 30° by a hydraulic mechanism.

Attached to each side of the drum are two twin-coil inductors, each rated at 300 kw., 575 volts, 50 cycles. Thus, the furnace has a total power rating of 1200 kw. This gives a maximum melting rate of 4.3 tons* per hr. Each of the inductors has a separate control unit connected to a single operating panel from which the entire melting furnace is automatically controlled.

Refractory blocks which line the furnace contain about 45% Al_2O_3 and 52% SiO_2. Expansion at 1175° C. (2150° F.) is about 0.5%. The material has a high crush resistance and its apparent porosity is less than 20%. Construction of the lining is based on the "deep throat" principle

*Weights in metric tons (2205 lb.) are used throughout the article.

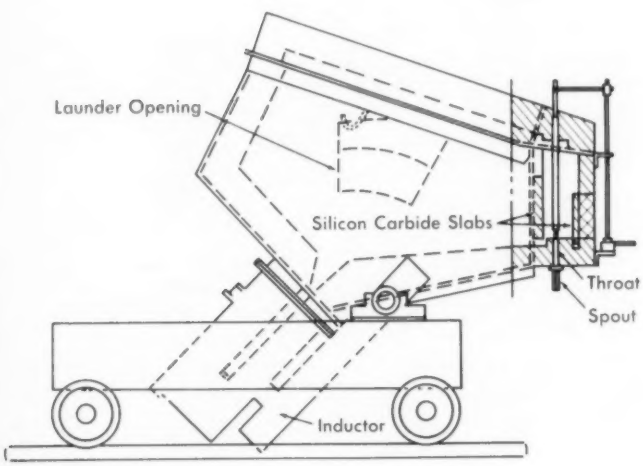


Fig. 3 – Pouring Furnace Maintains Molten Copper at Correct Temperature, ±2° C. When plug is lifted, the metal flows through zirconium throat, out of the spout to the chill mold

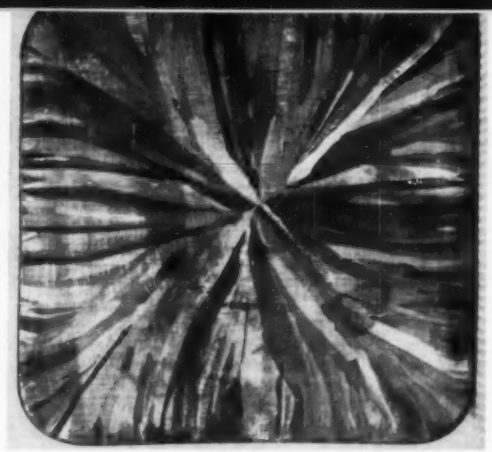


Fig. 4 – Macrostructure of Oxygen-Free Copper Produced by Continuous Casting

which permits the use of detachable inductors. A minimum of cement is used and blocks are ground for a close fit.

Preparing the Refractory

Meticulous care is necessary in preparing, drying, heating, and emptying the furnace to insure long lining life and economical operation. Every block must be set tightly and precisely into the lining. Of particular importance is the accurate positioning of the various "guide points" such as the openings for the spout launder, the inductors and the top bricks finishing the lining. The spout launder must be perfectly bonded with the furnace. At the inductor openings in the steel shell, the lining must have a completely smooth, flat surface to which the inductor can be attached.

When drying the refractory lining, one must remember that water cannot evaporate through the outer surface since this is a steel shell. For this reason drying takes almost a month. Air is first circulated by an electric fan for a week. Then charcoal is burned inside the furnace for another week. Finally, burners are used to bring the lining slowly up to at least 900° C. (1650° F.) so that its temperature is raised no more than 100° C. in a 24-hr. period. The furnace is maintained at 900° C. for one or two days before molten copper is charged.

Long Inductor Life

Special care is also necessary when preparing the refractory lining of the inductors. Lining begins with asbestos and mica sheets, continues with light insulating bricks, and ends with a rammed refractory to fill the joints. The ramming mixture used is a sillimanite with the approximate analysis 41% SiO_2, 56% Al_2O_3 and small amounts of CaO, MgO, and Fe_2O_3. Moisture content is about 4%.

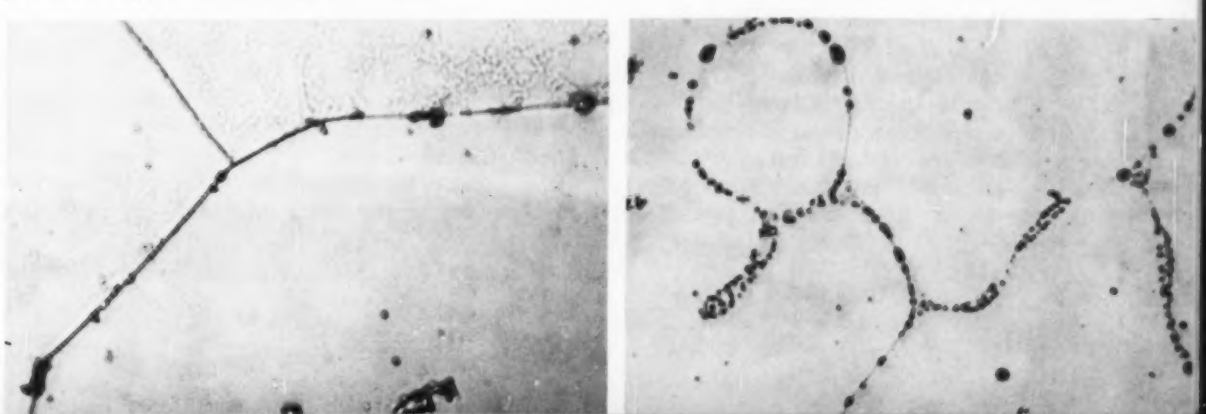
Inductor life depends on the care with which the lining is installed and the quality of the ramming material. Normal inductor life under continuous operation appears to be about 1½ years. At Fabrika Kablova Svetozarevo, the melting furnace inductors have been in continuous operation for 2½ years, have remelted 35,000 tons of copper cathodes, and are still in good condition.

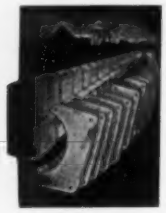
Before being put in operation, the inductors must be air-dried for about two weeks, then dried by electric heat for at least three months. The lining must be kept at a temperature between 60 and 80° C. (140 to 180° F.). During this time, it is transformed into a monolithic block. After the inductor is attached to the furnace drum but before charging the first molten metal, its channels are heated to at least 950° C. (1740° F.).

Starting the Melting Furnace

To start the furnace, the voltage to the secondary coils of the inductors is turned on and molten metal from a 4-ton portable furnace is charged and deoxidized if necessary. The furnace is then rotated 30°, the first two inductors are charged and power is applied at 35 kw. each. With the furnace rotated back to a horizontal position, the other two inductors are charged with molten *(Continued on p. 126)*

Fig. 5 – Micrographs Show Difference in Oxide Content of Oxygen-Free Copper (Left) and Tough Pitch Copper (Right). Oxides react with hydrogen at high temperatures to form water vapor and thus embrittle the metal





Short Runs

Welded Overlays for Corrosion Resistance

AN INTERESTING SITUATION EXISTS in the paper industry where the federal tax laws have a major influence on construction and maintenance. The industry uses a large number of pulp digesters, cylindrical vessels of carbon steel about 10 ft. in diameter and 40 ft. high. In the kraft or sulphate process, wood chips are cooked in a mixed solution of sodium hydrate sulphide and carbonate for a couple of hours up to 360° F. and 150 psi., after which the vessel is rapidly blown down and a new charge flushed in. Operating conditions are thus very severe and involve resistance to thermal cycling as well as to caustic solutions.

Formerly the steel digesters were unlined, but operating temperatures and caustic concentrations have been gradually increasing to a point where new equipment has been lined with Type 316 stainless. Such a lining may be a relatively thin sheet or strip either joined to the backing by a metallurgical bond or by closely spaced spot and seam welds. Some vessels, especially existing digesters which were not lined, have been protected by methods similar to "hard facing" – an overlay of closely spaced single-pass welds, overlapping in fact, using a higher alloyed electrode so the deposit will have close to Type 316 analysis after being diluted 20 to 40% by the carbon steel backing. Type 310, the original grade applied to digesters, is still being used and is still suitable for many applications. Although many of the old digesters have been corroded down to the safe limit, they have been kept in service by such "weld overlays".

A digester sheet lining is likely to crack by thermal stressing at the fusion line of the welded seams after a couple of years' service. Should it be replaced at a cost of $100,000 or repaired quickly at almost any cost? Now comes the income tax situation: A new digester would class as capital investment and as such be taxed at 52%. If it can be shown that the old one has not been completely amortized, the cost of repairs comes out of operating or maintenance and is deductible. This factor complicates the ordinary situation wherein sound engineering must consider the maintenance cost versus the replacement cost – the latter ordinarily being much higher than the cost of the repaired vessel f.o.b. site.

So an attractive scheme is to install a new lining on the interior (without dismantling the equipment) by depositing it as a welded overlay. Requirements for the job are a high-alloy electrode which can be manufactured commercially and deposited with inert gas shielding, and without weld cracks, in multiple-head automatic equipment on vertical surfaces. Speed should be limited so the weld deposit will weigh a minimum of 6.5 lb. per sq.ft. – that is, the overlay should average 0.15 in. thick. For this purpose the standard Type 310 weld wire (27-21 Cr-Ni) has given considerable satisfaction. Crucible Steel Co. recommends a bare wire electrode containing 0.12 max. C, 27 Cr (min.), 20 Ni (min.) and 1.5 Mo (nominal) for machine welding. For manual welding, molybdenum is added in the coating so the deposit after dilution by the carbon steel base will still approximate Type 316 analysis. (Electrode wires analyzing higher in molybdenum are rather difficult to make.) International Nickel Co. has worked with a 30-25-6 Cr-Ni-Mn electrode which deposits sound weld overlays having a corrosion rate by Huey test only half that of Type 310 + Mo.

By the very nature of the application and the variations in operating conditions, it will take some time for any general agreement (if ever) as to the optimum electrode and welding process for this important work.

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LETTERS TO THE EDITOR

In Harold Roast's article on the casting of Big Ben ("A Century Old Test of Metal", December 1960, p. 99), our readers may have been surprised to read in the caption on p. 100 that Big Ben hangs "atop Westminster Abbey". This was a slip of the editor's pen. Big Ben still strikes the hour in the Clock Tower of the Houses of Parliament – as it has for more than 100 years.

Corrosion Resistance of Lead Alloys

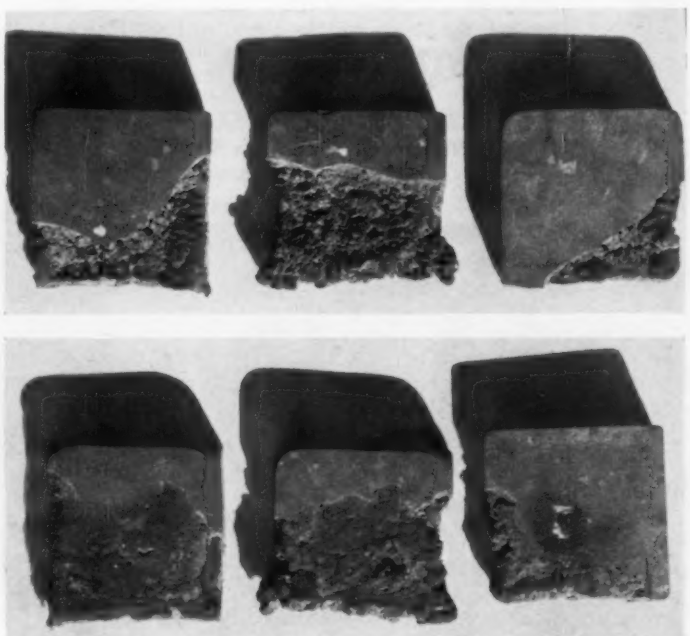
JOHANNESBURG, SOUTH AFRICA

We in the metallurgical and research department of African Explosives and Chemical Industries, Ltd., are much concerned with the corrosion resistance of commercial and reclaimed lead, particularly as installed in sulphuric acid plants. Consequently we read with interest the article in February (1960) *Metal Progress* entitled "A New Class of Lead-Base Alloys", hoping that the work reported therein by Messrs. Williams, Houck and Jaffee would lead to an improvement in what is frequently called "chemical lead". However, their finding that 30% copper powder dispersed in lead accelerates greatly the corrosion of lead in hot H_2SO_4 is not in conformity with our tests of lead-copper alloys made by conventional means and containing up to 1% copper.

We accept, in the absence of a better criterion, that the flash* test described in British Standard 334: 1934 indicates cheaply, quickly and reliably the acceptability of consignments of chemically pure lead for service in hot sulphuric acid. It is fairly common knowledge that the presence of antimony in excess of the requirements (30 ppm.) of the above specification causes a marked fall in the flash test value, and the effect of silver in excess of 20 ppm. is believed to be similar. On the other hand, the limitation of 30 ppm. of copper seems to be un-

*In the flash test a small square sample of lead is immersed in concentrated H_2SO_4, and a thermometer is fixed so its bulb is near the sample without actually touching it. Heating is at the rate of 40° C. per min. The "flash point" is the temperature at which the bulb is obscured by precipitation of lead sulphate.

Fig. 1 – Flash Test Produces Violent Reaction on the Upperside (Top) and Underside (Bottom) of Small Samples of Lead Alloy Containing 1% Silver



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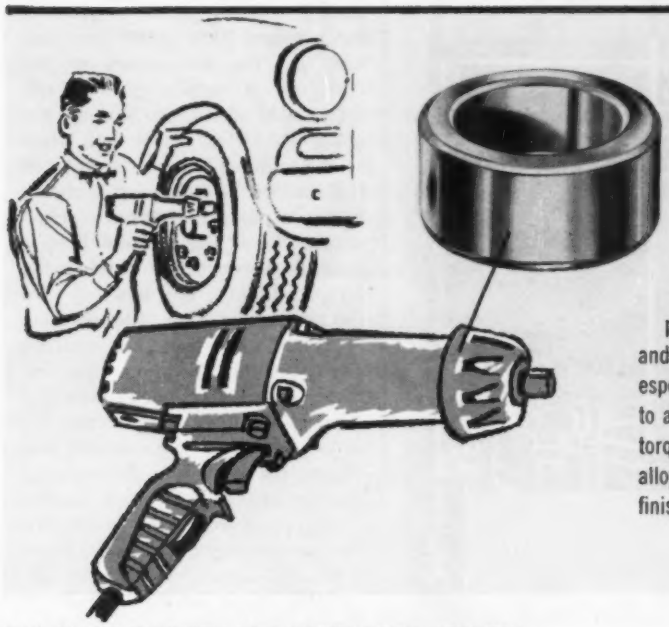

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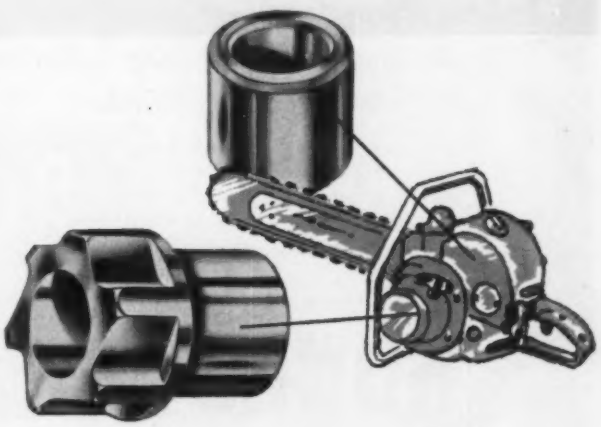

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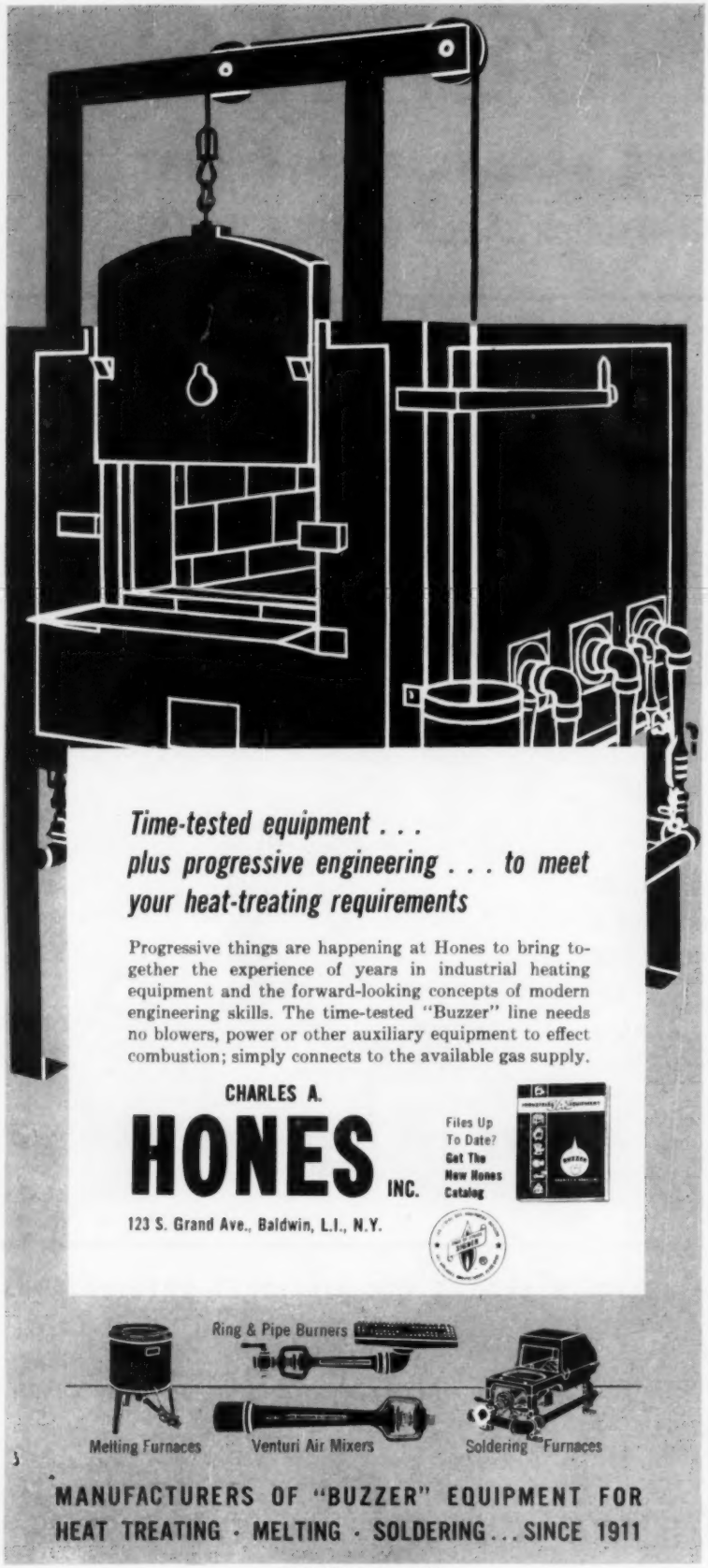
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Letters . . .

warranted. At any rate, we regularly use lead containing 0.06 to 0.07% copper in sulphuric acid coolers, and find that any fall in corrosion resistance is clearly outweighed by the gain in fatigue and creep resistance.

To check this matter, we have performed flash tests on "pure" lead alloyed with copper in proportions ranging from 10 to 10,000 ppm. and find that the temperature of the flash test is surprisingly constant, the mean of all our tests in this range being $309 \pm 8^{\circ}$ C. Tests with silver as the additive entirely change the character of the attack and as shown in Fig. 1 produce a violent reaction which, unless the external heat is withdrawn, completely dissolves the sample within a few minutes. On the other hand, even after 25 min. at 315° C. there was little evidence of flash in the 1% copper alloy, but the acid turned blue, indicating that copper was dissolving preferentially at these high temperatures and protecting the lead from the expected flash-disruption of its sulphate film.

It appears from these results that the manufacture of a lead alloyed with 1% copper, if commercially possible, might be of great value to the chemical industry. In sulphuric acid production, any temporary interruption of the water to cooling coils may cause their rapid failure by intercrystalline cracking and corrosion – not by wastage or by pitting corrosion. Resistance to short-time, high-temperature exposure therefore becomes of greater importance than resistance to long-time, low-temperature exposure. Our work suggests that this can be achieved by the addition of approximately 1% copper to pure lead.

The work of Williams, Houck and Jaffee shown in their Table II indicates that concentrated dispersions of much more copper in lead do not increase corrosion resistance to the acids and temperatures reported. Probably the more dilute dispersions should be investigated. We would be pleased to know if any readers of *Metal Progress* could confirm or refute our own results.

R. E. Leyman
Chief Metallurgist
Consulting Engineer's Department
African Explosives &
Chemical Industries Ltd.

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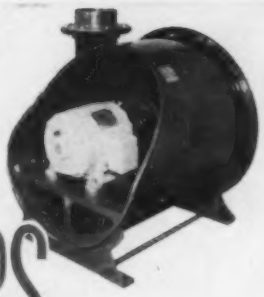

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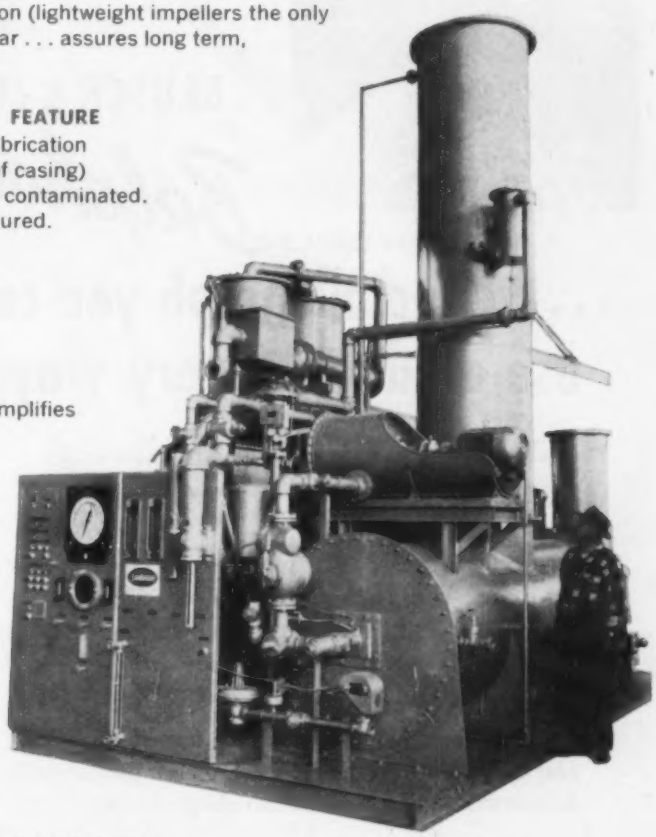

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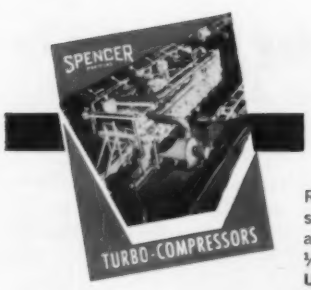

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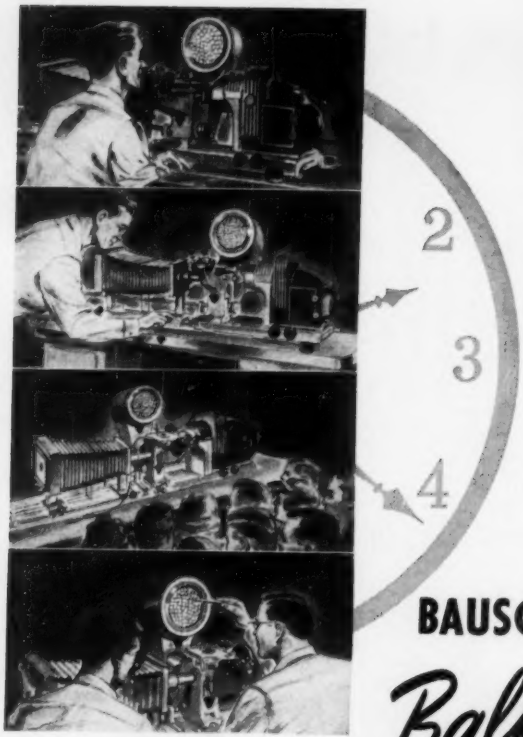

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Iron Making in Africa 100 Years Ago

WORCESTER, MASS.

Your readers might be interested in a report on primitive iron making from my son Mark in Gabon, French Equatorial Africa. The iron makers were two tribes – the Fang and Banjabi – who gained a position of great influence perhaps a hundred years ago because they produced iron for axes, spears, arrows and knives. Today, with imports being readily available, these skills are nearly forgotten.

The northern tribe, the Fang, lived in a region rich in very small deposits of high-grade ore. They would set up a furnace on the site of an ore deposit, work the deposit and then leave. The furnaces were small and made of fire-baked clay with a stone grating. Ore was poured in at the top of the furnace, and heated by the fire under the grating. Air was blown in by wood and skin bellows through passages under the ground, lined with hollowed stones, and the pigs were cast in the ground.

Although the fragile furnaces had to be replaced continuously, the pipes, bellows and grating could be used many times. The pigs were not only used to make weapons but also as money (principally to purchase brides) and some of this "currency" is still in circulation.

CARTER C. HIGGINS
President
Worcester Pressed Steel Co.

A New Fracture Test for Alloy Steels

LIVERPOOL, ENGLAND

The test described by D. L. Newhouse and B. M. Wundt in "A New Fracture Test for Alloy Steels" (*Metal Progress*, July 1960, p. 81) is almost identical to one I developed in 1957 from a suggestion by A. H. Cottrell, at the Atomic Energy Research Establishment in Harwell, England.

We were concerned with the development of a small test which would separate the energy needed to form a fast running crack from

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Fusion point 3220 F. This brick offers an excellent balance of properties to assure superior service. It provides approximately 5% more alumina content and lower total impurities than competitive brick. It has excellent spalling resistance.

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Circle 845 on Page 48-B

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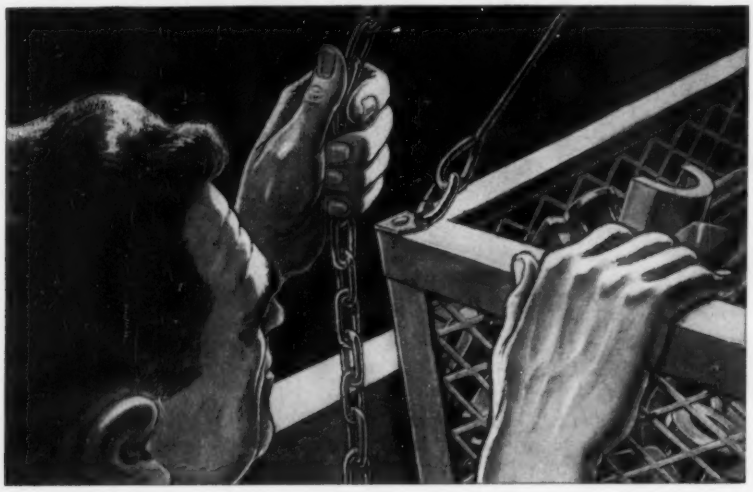

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Circle 846 on Page 48-B

Letters . . .

the energy required to propagate such a crack. By nitriding the surface layers, the energy needed to form a fast crack could be reduced to a minimum and thus the resistance of the base material to a fast running crack could be measured. For specimens with a nitride layer, there was a very sharp transition between ductile and brittle fracture and the transition temperature was increased by about 40° C. (104° F.).

Although this test has a number of potential developments (some of which are under study here), there are two serious limitations in its present form: First, the steel specimens have to be heated to about 600° C. (1112° F.) during the production of the nitride layer; this may affect the properties of the steel, each steel being affected differently. Second, it would be difficult to standardize the nitriding procedure from one steel to another to obtain a nitride layer of constant thickness and similar mechanical properties.

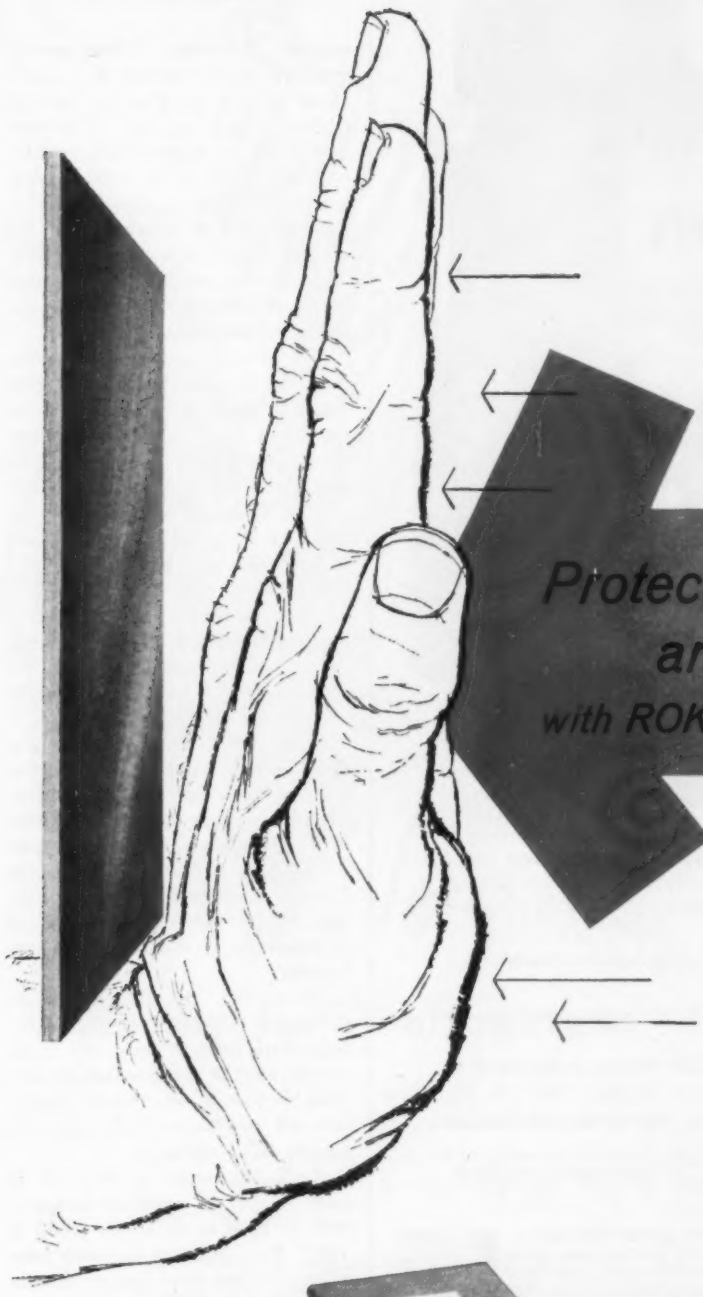
Because of these limitations, I am now considering other methods of producing a brittle layer on the surface of steel which do not involve heat treatment.

This work was published as an Atomic Energy Research Establishment Report M/R 2432 in November 1957 and in the *Journal* of the British Nuclear Energy Conference, Vol. 4, No. 3, July 1959.

DEREK HULL
Department of Metallurgy
University of Liverpool

AUTHORS' REPLY: Our test is indeed very similar to Mr. Hull's and we regret that we did not learn of his work earlier in our investigation. Our nitriding process is conducted at 975° F. (524° C.) considerably below the tempering temperature used for the materials under study, and thus has not caused any problem with alteration of hardness or tensile properties. As for temper embrittlement, even those alloys which are susceptible have not been significantly changed with respect to fracture appearance transition temperature. Nitriding adds very little to the embrittlement produced during normal heat treatment.

D. L. NEWHOUSE
B. M. WUNDT



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Circle 847 on Page 46-B

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Circle 848 on Page 48-S

Oxygen-Free Copper . . .

(Continued from p. 115)

copper. Charcoal is then spread over the metal surface in a layer about 4 to 6 in. thick to prevent oxidation, and the furnace is then slowly charged to its normal capacity – about 13½ tons – with copper cathodes. The charging door is built so that it opens under the weight of the cathodes and closes under its own weight. This arrangement prevents contamination of the furnace atmosphere.

The rate of discharge of molten metal to the closed launder is governed by the voltage available from the power supply. With full voltage available, the maximum melting rate is 4.3 tons per hr. Normally, however, it varies between 3.2 and 4.0 tons per hr. Furnace temperature is held near 1175° C. (2150° F.) but fluctuates within ± 20° C. Variations of this order are a problem in continuous casting, hence the need for a pouring furnace in which the temperature of the metal can be controlled more accurately.

From the melting furnace the metal flows down the spout launder into an electrically heated launder. This is located at the axis of rotation of the furnace and the two are connected by a seal which permits the furnace to rotate but prevents leakage of gas. Metal is heated by rod elements as it flows through the launder.

Electrically, the launder is divided into three sections which have individual control units and autotransformers to regulate voltage and, thereby, temperature. Each station is rated at 7½ kva., 575 volts, 50 cycles, single phase.

A thermocouple is attached to each section to maintain temperature at 1030 to 1050° C. (1885 to 1920° F.). Heating elements have a long life and more than six months pass before their efficiency decreases to such a degree that they must be replaced.

The pouring furnace (p. 114) can be tilted forward and backward and at the same time be moved horizontally along rails. It has four main parts – a body of welded steel, spout, lid and inductor. Both the inductor and the area around the furnace opening where it is attached

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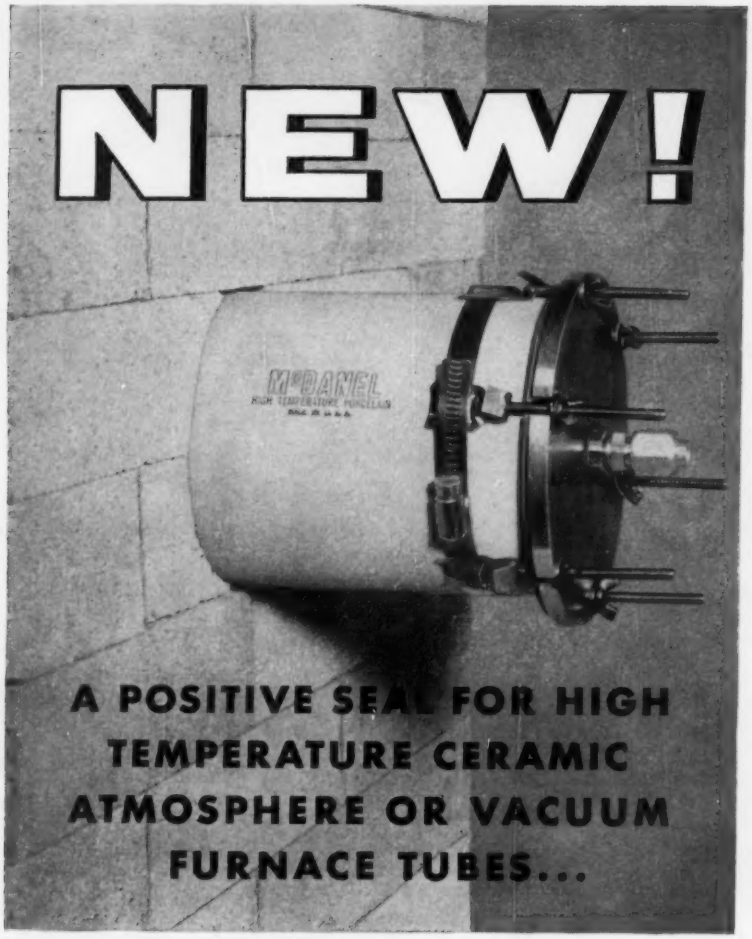

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Circle 850 on Page 48-B

Oxygen-Free Copper . . .

are lined with rammed sillimanite. Remaining portions of the furnace are lined with refractory bricks having ground surfaces. Quality of the refractories is the same as that used in the melting furnace and the same drying, preheating and charging procedures are employed.

On page 114, Fig. 3 shows details of the pouring chamber. This consists of a silicon carbide muffle with heating elements and a zirconium throat to which the downspout is connected. Pouring is regulated manually by a plug which closes or furnace. Lining life of the furnace

In addition to a charcoal layer, the metal is also protected by a reducing atmosphere in the pouring furnace.

Close Temperature Control

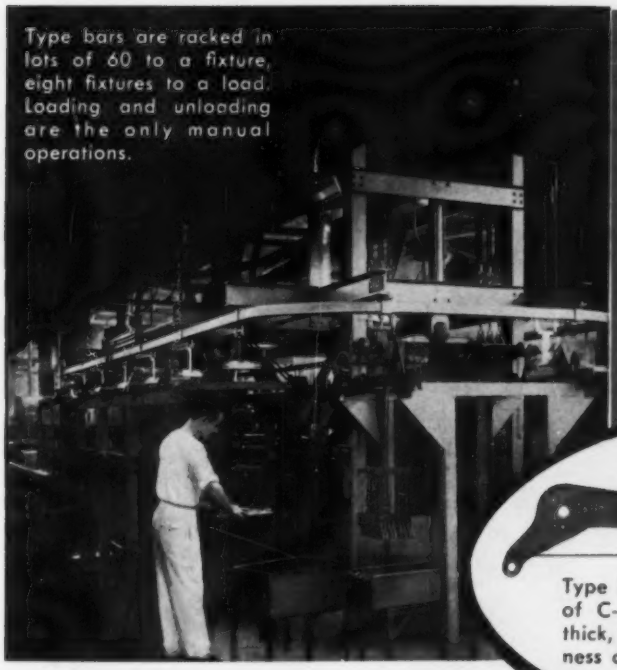
The pouring furnace inductor is rated at 100 kw., 575 volts, 50 cycles, single phase. It has its own control unit and electrical apparatus for completely automatic operation and is lined and installed in the same way as those used with the melting furnace. Normal lining life is three years under continuous operation.

Holding capacity of the pouring furnace is about 2½ tons. Before tilting the furnace for pouring, the metal temperature is increased to 1200° C. (2190° F.), but the usual pouring temperature – 1150 to 1160° C. (2100 to 2150° F.) – is reached within 10 to 15 min. Temperature fluctuations in the pouring furnace are held to ±2° C., a factor of great importance to successful continuous casting.

Both the pouring and melting furnaces are automatically controlled by thermocouples and electric pyrometers. Otherwise it would be impossible to regulate temperature because the furnaces are completely enclosed.

Wire Bars Continuously Cast

The only casting method used at our plant is continuous casting with a Junghans-Rossi machine. This machine can operate at casting speeds up to 60 in. per min. (for cross sections of 4 × 4 in.) or about 8 tons per hr. Wire bars from 2 × 2 in. to 6 × 6 in. in cross section can be cast. Casting length is adjustable up to 60 in.; however, our pres-



Type bars are racked in lots of 60 to a fixture, eight fixtures to a load. Loading and unloading are the only manual operations.

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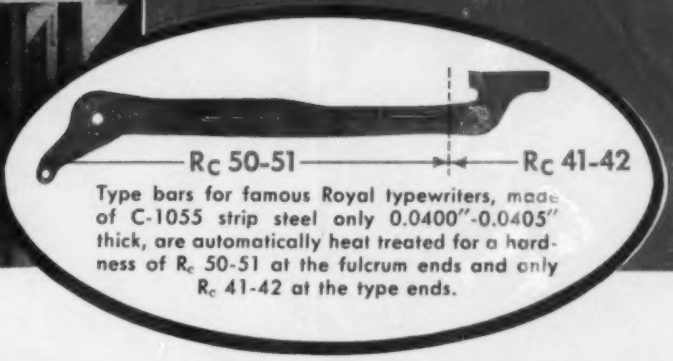

Type bars for famous Royal typewriters, made of C-1055 strip steel only 0.0400"-0.0405" thick, are automatically heat treated for a hardness of R_c 50-51 at the fulcrum ends and only R_c 41-42 at the type ends.

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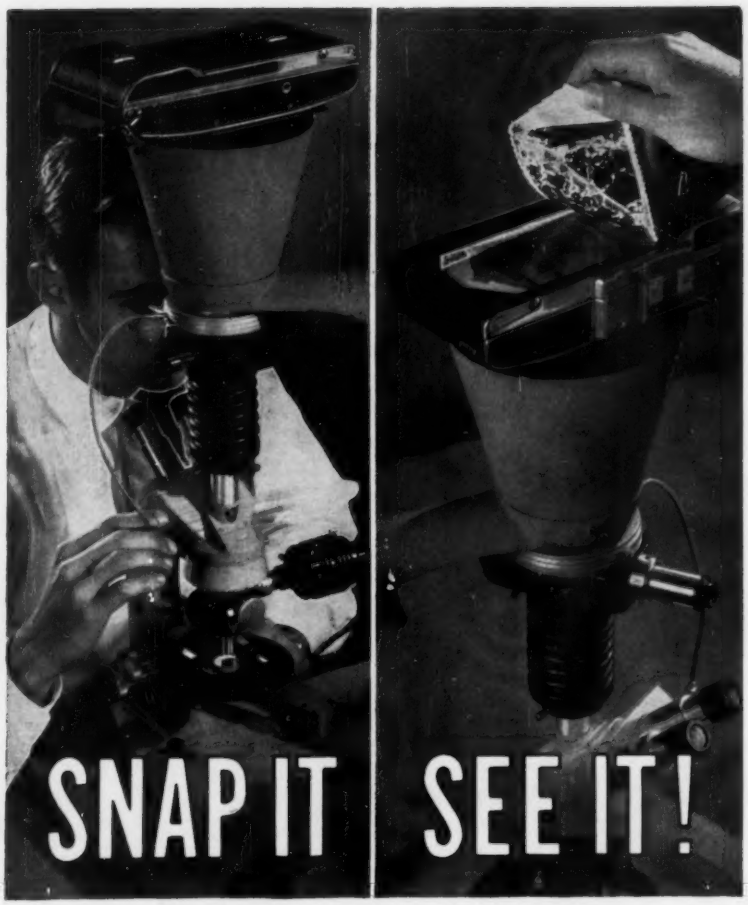
Circle 851 on Page 48-B



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Circle 852 on Page 48-B

Oxygen-Free Copper . . .

ent standard length is about 45 in.

Main components of the casting machine are the casting table with chill mold and water sprays (upper unit), the main drive and transport rolls (middle unit), and the saw with its hydraulic mechanism for cutting the wire bar (lower unit).

The chill mold is arranged in the center of the casting table at the vertical axis of the saw clamps. Transport rolls hold the wire bar in position. During casting the platform moves down as the cast wire bar solidifies. After moving from 0.5 to 1.5 in., it returns rapidly back to its original position. Upward movement of the mold is about three times the speed of the downward movement.

Before starting operation, the casting machine must be synchronized. This means that the downward motion of the chill mold must be the same as the peripheral speed of the transport rolls so that there can be no relative movement between the mold and the bar being cast.

During casting the wire bar cools in the chill mold and emerges at a temperature of 850 to 900° C. (1560 to 1650° F.). The bar is cooled to room tempearture by water sprays and then passes through a rubber wiper.

As the wire bar is withdrawn from the mold by the transport rolls, it pushes down a basket which receives cut lengths. When the bar reaches the desired length, the flying saw is actuated. Clamps grasp the wire bar and the saw platform then moves downward with the wire bar through a series of steps. After the wire bar is cut, the saw is withdrawn to its original position and the platform is brought back to its upper starting position. In the meantime, the basket is lowered pneumatically and the wire bar is transferred to a gravity conveyer. The cycle is repeated for each successive cut.

Mold Construction

The chill mold used for casting oxygen-free copper consists of a water cooled copper block. The profile to be cast is cut from the center of this block and the inner surfaces are machined, polished and chromium plated to obtain the smoothest possible surface, thus reducing fric-

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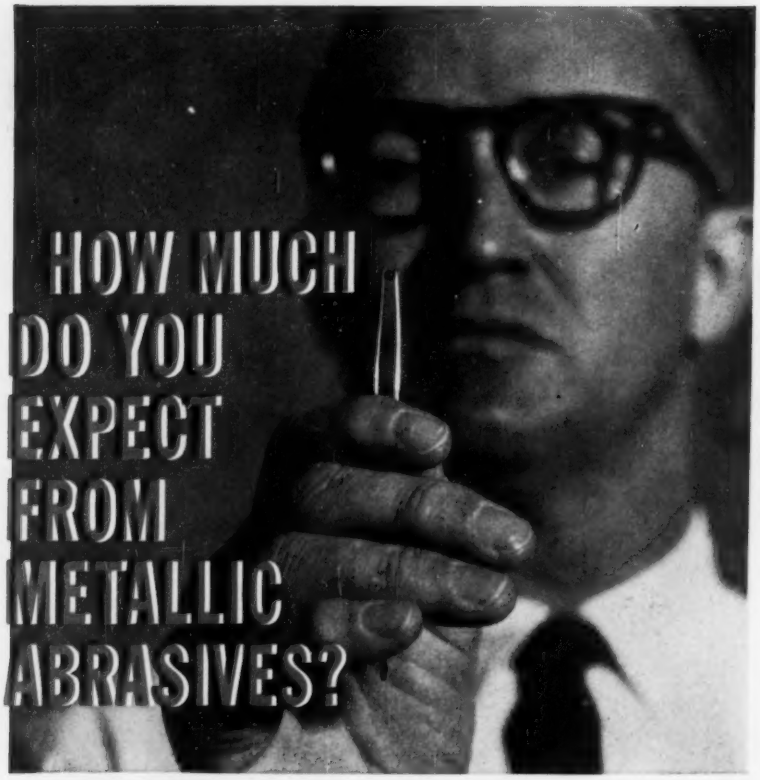
Circle 853 on Page 48-8



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Circle 854 on Page 48-B

Oxygen-Free Copper . . .

tion between cast bar and mold surface. During any interruption of the casting process, the mold is cleaned and polished with a special polishing material. Completely smooth surfaces are obtained and no milling of the wire bars is required.

To prevent contamination of the molten metal at this point, it is protected by gas which flows over the copper into a hood placed over the top of the chill mold. In addition, lubrication of the bar is supplied by butane gas introduced through a ring. At the high metal temperatures and with no air present, the butane decomposes to hydrogen and carbon. The carbon precipitates as soot on the metal surface and is drawn against the mold walls.

The proportions of protective gas and butane in the chill mold are of great importance. Just enough gas should be introduced to cause a gentle flow out through the hood. If the flow of butane is too fast, spots and occlusions are formed which appear as impurities on the wire bar surface. More important – density of the copper drops.

Correct cooling in the mold is another important aspect in continuous casting of copper. Soundness of the casting (Fig. 4, p. 115) depends on uniform cooling in the mold and by water spray. A slight deviation from optimum cooling rate leads to rejects. Roughly speaking, one third of the heat in the bar is removed in the mold. The remainder is removed by the sprays. In casting a bar with a 4×4 in. cross section, about 70 to 90 l. of water per min. is passed through the mold and from 130 to 200 l. per min. is used in sprays.

To start the casting process a wire bar is inserted about two thirds into the chill mold and the space between mold and casting is filled with asbestos strips. The mold table is set at its highest position and the speed is set for starting.

Up to the present, the maximum production for any one day has been 103 tons. Normal daily production runs around 80 tons.

It is significant to note that deoxidized copper and copper alloys present no problem in continuous castting, but electrolytic tough pitch copper from reverberatory furnaces has

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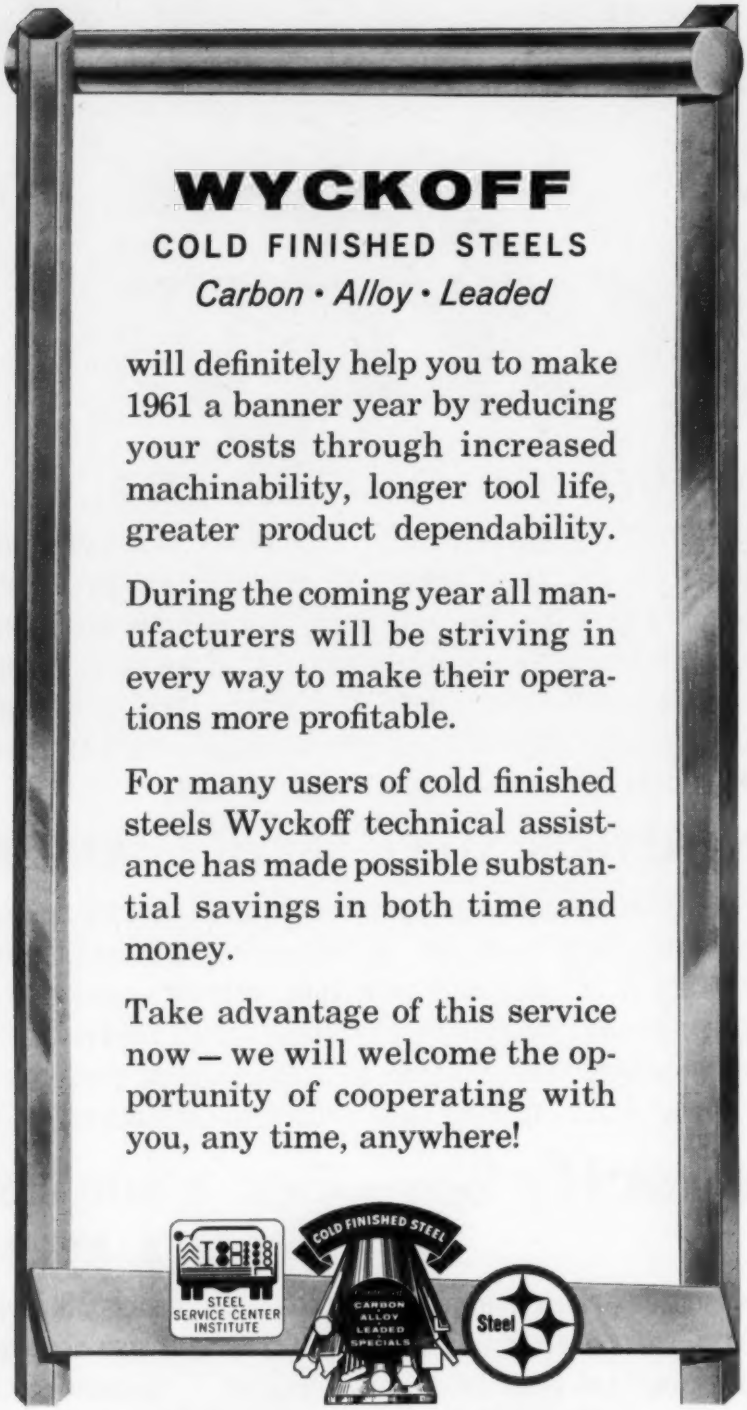
Circle 855 on Page 48-B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Circle 856 on Page 48-B

Oxygen-Free Copper . . .

not yet been cast successfully by a continuous process. One reason may be that with oxygen-free copper there is greater shrinkage during solidification, a characteristic which prevents continuously cast bars from jamming in the mold and cracking.

Reducing Gas Protects Molten Copper

It must be remembered that production of oxygen-free copper is basically an operation in which high-quality copper cathodes are melted and cast into suitable shapes (in this instance as wire bars). To maintain the quality of the cathode copper, it is remelted and cast under a protective atmosphere. At Fabrika Kablova this gas is produced from charcoal and sent through a gas scrubber for washing and cleaning, then water vapor is removed and carbon dioxide is reduced to carbon monoxide.

Charcoal is burned in a small gas producer lined with refractory brick. This makes producer gas with an approximate composition of 16% hydrogen, 27% carbon monoxide, 5% carbon dioxide, 1% methane, remainder nitrogen. The generator can burn up to 20 kg. of charcoal per hr. Our normal production requires about 5.8 kg. of charcoal per hr.

This gas is then cleaned in a scrubber to remove dust and tar and, if necessary, sulphur dioxide. The scrubber is filled with washed coke having a grain size of ⅜ to ¾ in. in the lower half and ¾ to ½ in. in the upper half. Gas is discharged from the bottom.

Although charcoal was chosen because of its low sulphur content, it is necessary to insure that this element does not contaminate the copper by directing the gas through a sulphur remover containing wood shavings impregnated with iron oxide (Fe_2O_3). This reacts with the sulphur (present as hydrogen sulphide) to form pyrites (Fe_2S_3) and water vapor.

The cleaned producer gas is then sent to a converter at a pressure of 0.211 atm. where it is mixed with air in carefully controlled proportions, compressed and burned. Burning is performed in a reaction chamber filled with catalytic bricks which help to complete the combus-

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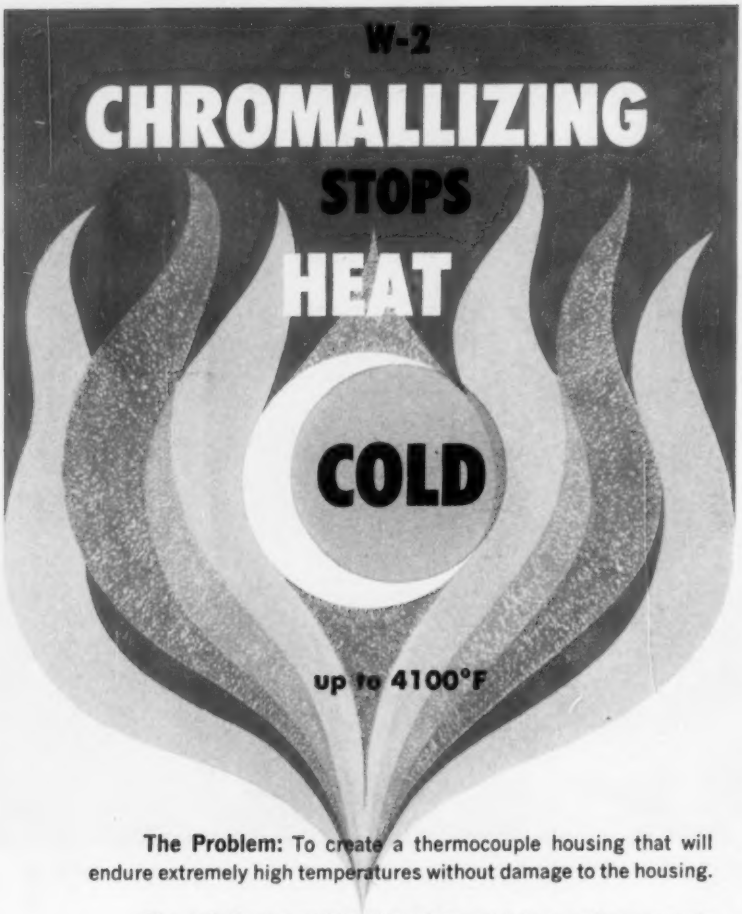
. . . at Alabama Metallurgical Corp., Selma, Ala., where thirty Electromax® controllers helped them swing into full production after only a few months of operation. Magnesium at this new plant is produced from briquettes of CaO, MgO, FeSi and CaF_2 which are reduced at 2150 F in evacuated retorts. Since startup in late 1959, Electromax has been consistently holding retort temperatures within ± 5 F. Additional instrumentation includes Speedomax® H which is recording flue and feed-zone temperatures of the lime burner kiln, and controlling temperatures of magnesium bath for casting into ingot and pig. You'll find L&N instruments providing equally dependable control for thousands of applications where heat is used . . . helping to produce both process economies and a quality product. When such significant savings stem from such a modest investment, *it pays to get the best.* For details about L&N controls for modernization or expansion, contact your nearest L&N office or write 4927 Stenton Ave., Phila. 44, Pa.

LEEDS Instruments NORTHRUP Automatic Controls • Furnaces

With Electromax holding retort temperatures within ± 5 F, Speedomax G multiple-point recorders provide a permanent record of furnace temperatures.

Circle 857 on Page 48-B



The Problem: To create a thermocouple housing that will endure extremely high temperatures without damage to the housing.

The solution: A CHROMALLIZED molybdenum thermocouple housing. This housing withstands temperatures up to 4100°F. Other applications are structural parts for re-entry vehicles, high temperature testing grips, and ramjet engine components.

What is Chromallizing?
A proven process for diffusing chromium and other elements into the surface provides an alloy case which is integral with the base metal. It can't peel or flake. the chromium and other elements diffuse uniformly into recesses, pores, cracks and even blind holes.

CHROMALLIZING processes are also being used to protect superalloys for jet engine parts and to protect ordinary steel against wear, oxidation and corrosion.

WRITE FOR ILLUSTRATED BULLETIN PC

Chromalloy corporation

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ELmwood 8-5900

CHROMIZING CORPORATION, LOS ANGELES, CALIFORNIA
PROPELLEX CHEMICAL DIVISION, EDWARDSVILLE, ILLINOIS
Propellents, cartridge actuated devices, explosives and special chemicals.
ELYRIA FOUNDRY DIVISION, ELYRIA, OHIO. Quality gray iron castings.
SINTERCAST DIVISION, YONKERS, N. Y. Machinable carbides & nuclear materials.

Circle 858 on Page 48-B

Oxygen-Free Copper . . .

tion process, thus changing the composition of the gas to carbon dioxide, nitrogen and water.

Some of the moisture is removed in the cooler which brings the gas to a temperature of 17 to 18° C. The gas is then passed through a refrigerator which chills it to 2° C., thus extracting most of the remaining water.

This gas, now substantially water-free, goes to a retort of heat resistant steel which is filled with charcoal heated to 1050° C. (1920° F.). It enters the lower end of the retort, passes through the glowing charcoal, which reduces the carbon dioxide to carbon monoxide, and exits through a dust filter. The resulting gas has a composition of 20 to 25% carbon monoxide, 0.5 to 1% carbon dioxide, 0.5 to 1% methane, 0.5 to 1% hydrogen, remainder nitrogen. This is the atmosphere which protects the molten copper during melting and casting operations.

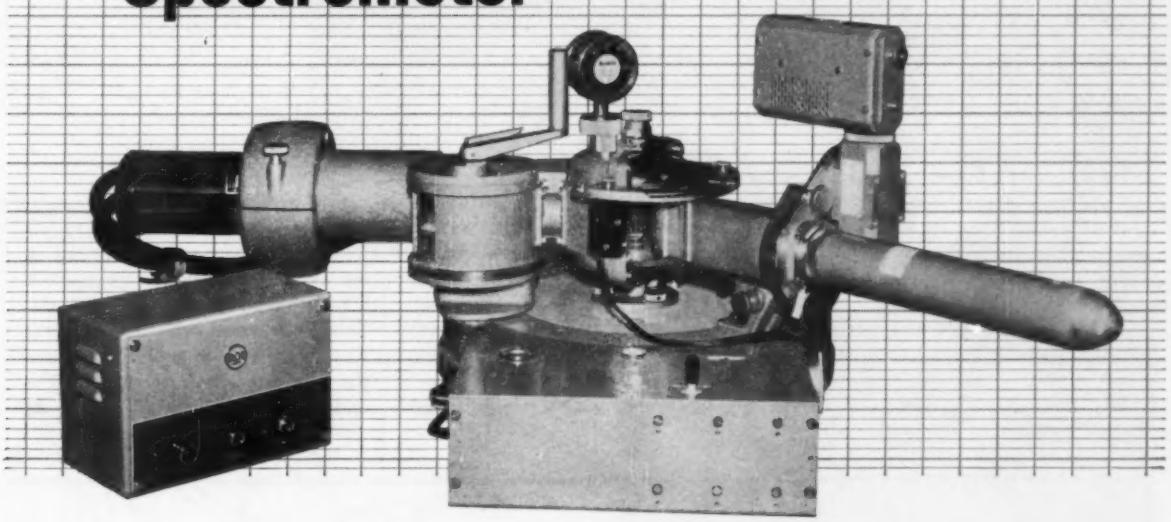
Process and Product Control

Continuous melting and pouring, together with the full mechanization and automation, allows a high degree of control and accuracy.

Process control is carried out at five key points where information is recorded at specified intervals to indicate the condition of that particular portion of the equipment. In addition to the standard records of instrument readings, every change is noted, together with the exact time of occurrence. This is often accompanied by remarks and comments by the foreman in charge of the section. Records of this kind present a clear picture of the process. They also permit close control and supervision.

The data collected during each shift also serve as a basis for daily reports on plant operations which list the amount of metal melted, hourly melting rate, average melting rate in tons per hour, amount of metal poured, analysis of casting machine operation, yield, amount of rejects and scrap, electric power consumption per ton of cast copper, consumption of charcoal and other materials required in the operation and maintenance of the plant. Analysis of such information has already made it possible for us to reduce power

New from RCA... X-Ray Vacuum Spectrometer



for analysis of the lighter elements

Especially suited to the X-ray spectro-chemical analysis of elements below atomic number 22, RCA's new Vacuum Spectrometer permits the use of three samples at one time. Samples—powders or solids—can be moved in and out of the vacuum path without breaking vacuum. The need for helium is eliminated, but air or helium can be used when desired. A flange connects the sample chamber directly to the X-ray tube, making higher intensities possible, and eliminating the need for a second beryllium window. From a cold start the recommended vacuum of 0.1mm or 100 microns can be reached in less than two minutes. Designed primarily for the analysis of lighter elements, the Vacuum Spectrometer can be used to advantage with heavy elements to give higher intensities.

The Vacuum Spectrometer is one of a wide range of attachments and accessories available for RCA X-Ray Diffraction and Spectroscopy equipment which contribute to its extreme flexibility of application. Installations already made in some of the nation's leading research laboratories are demonstrating the efficiency, technical excellence and versatility of these instruments.

Installation supervision and contract service for RCA Electron Microscopes and X-Ray Diffraction and Spectroscopy Equipment are available through the RCA Service Company.

For details on the new Vacuum Spectrometer or RCA's full line of X-Ray Diffraction and Spectroscopy equipment, write to RCA, Dept. R-72, Building 15-1, Camden, New Jersey.

Vacuum Spectrometer and a Diffractometer mounted on Crystalloflex IV and connected to Electronic Circuit Panel

The Most Trusted Name in Electronics
RADIO CORPORATION OF AMERICA

Circle 859 on Page 48-8

Oxygen-Free Copper . . .

consumption per ton of finished product from 470 to 350 kw-hr., consumption of charcoal from 6.1 to 4.3 kg. per ton, and increase the yield from 98.5% to 99.2%.

Constant Test Program

To check the quality of the wire bars we make visual inspections, measure specific gravity of every 35th bar and perform physical and chemical tests. It is standard procedure to take a sample for complete testing every four hours of casting, or twice per shift. A greater number are tested when copper from several sources is being melted. Generally we have found that with the continuous casting process there is little danger of sudden changes in production.

Tests are made to determine electrical conductivity, bending, torsion and rupture properties, elongation and macro and microstructure. An embrittlement test is also performed by bending specimens after heating them for 30 min. in hydrogen at 850° C. (1560° F.). To pass A.S.T.M. Standard B-170, the samples must withstand at least eight to ten bends. Ordinary electrolytic tough pitch copper which has a normal oxygen content will break before one bend has been completed.

Table I – Comparison of Properties of Oxygen-Free and Tough Pitch Copper Wire

	Oxygen-Free	Tough Pitch
Specific gravity, kg. per cu.dm.	8.90 to 8.94	8.50 to 8.75
Tensile strength*, kg. per sq.mm.	42 to 43.5	40 to 44.2
Elongation	2%	2%
Specific conductivity, ohms per meter per sq.mm.	58.9 to 59.3	58.2 to 58.6
Number of bends		
Before exposure to hydrogen	15 to 18	10 to 12
After exposure to hydrogen	8 to 12	0 to ½

*Tensile strength and elongation were determined for hard, drawn wire; specific conductivity and bend tests were conducted on annealed wire.

Table I gives comparative values for oxygen-free copper produced at our casting shop and for tough pitch copper from a reverberatory furnace. Both were tested at the same laboratory. Figure 5 on p. 115 compares the microstructures of oxygen-free and tough pitch copper.

they're not "exotic" any more...

at least not for engineers in the Custom Services Department at Nuclear Metals, Inc. During the last ten years, many of the alloys and special combinations symbolized here have been actually fabricated to a specific part or shape needed by a variety of industrial customers. The Custom Services Department has been staffed to expedite the conversion of your metal, your material, into a rod, tube, wire or other shape. One billet or one hundred billets can be melted, extruded, rolled, drawn, swaged, analyzed or tested at N.M.I. All sorts of materials — soft, hard, common, rare, refractory, toxic, reactive, radioactive — can be handled with the know-how and facilities of the world's largest privately owned metallurgical research laboratory.

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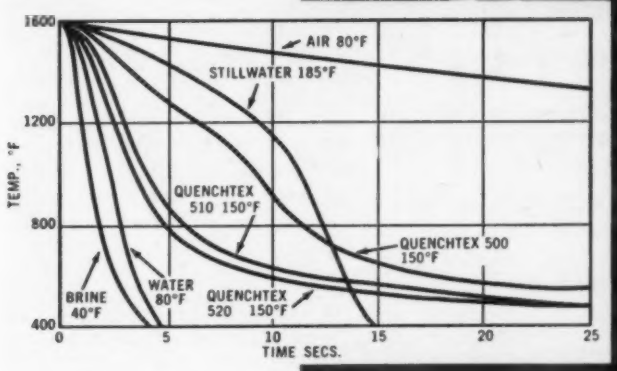
PRACTICAL SHAPES FROM NEW MATERIALS

Photo taken at Hoover Ball and Bearing Company, Ann Arbor, Mich., shows parts coming out of QUENCHTEX bath.

Cooling rates of several quenching media including QUENCHTEX 500, 510 and 520.



Get uniform hardening...improved grain structure... longer oil life . . . with TEXACO QUENCHING OILS

Because steels vary so widely in analyses, Texaco offers a complete line of quenching oils with different cooling curves:

QUENCHTEX 500—a *conventional* quenching oil;
QUENCHTEX 510—a *medium-speed* quenching oil;
QUENCHTEX 520—an improved *high-speed* quenching oil.
MARQUENCH—a *hot* quenching oil, for full hardness with minimum distortion.

The difference in cooling rates of QUENCHTEX oils, as shown in the chart, are functions of their composition. QUENCHTEX 500 is a straight mineral oil, while QUENCHTEX 510 and 520 are additive types, prepared from refined paraffin base crudes.

QUENCHTEX OILS give you these important advantages:

- Exceptional stability at recommended temperatures
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- *Compatibility* with most other mineral base quenching oils

A Texaco Metalworking Engineer will be glad to evaluate your system and take necessary steps to recommend the proper Quenchtex for make up. Contact the nearest of the more than 2,300 Texaco Distributing Plants or write: Texaco Inc., 135 East 42nd Street, New York 17, N. Y.

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Circle 861 on Page 48-B

PERSONAL MENTION

David Stahl – received his M.S. degree in metallurgical engineering from Ohio State University in August 1960 and is now in the materials section of Nuclear Development Corp. of America, White Plains, N.Y.

Felix P. LaIacona – now section chief of the metallurgy (materials) laboratory for the National Aeronautics and Space Administration at the Redstone Arsenal, Huntsville, Ala.

Ronald A. Kelsey – has returned to the Alcoa Research Laboratories after five years with the Electric Boat and General Atomic Divisions of General Dynamics Corp.

Livius Maria Botar – from technical information officer to scientific coordinator to the operations department of Brazilian National Steel Co., Volta Redonda, Brazil.

Larry S. Klass – from toolsteel metallurgist, Thompson-Ramo-Wooldridge, Inc., Cleveland, to senior metallurgical engineer, Avco Corp., Nashville, Tenn.

J. Thomas Hodges – from assistant to the director of technical services in J&L's general office in Pittsburgh, to metallurgical service engineer, flat rolled products, assigned to the eastern territory with headquarters in Pittsburgh.

Frank M. Lister – from chief materials engineer to director of quality control, Kaman Aircraft Corp., Bloomfield, Conn.

Norman F. Tisdale, Jr. – now executive vice-president of the Pittsburgh Metals Purifying Co., Mars, Pa.

John W. Dowding, vice-president of engineering at Brubaker Tool Corp., Millersburg, Pa. – now heads the manufacturing operations of the company.

Oliver H. Cook – now manager of Vanadium-Alloys Steel Corp.'s newly organized cast-to-shape products department.

Harvey A. Anderson

HARVEY A. ANDERSON, *Metal Progress* consulting editor in Tucson, Ariz., has been in charge of the Tucson office of Electronic Consultants, Inc., technical and commercial advisors in New York and Boston, since his retirement from Western Electric Co. a year and a half ago.

He graduated from Northwestern University in 1916, then worked for the National Bureau of Standards and the U.S. Naval Aircraft Factory in Philadelphia, where he was head of the material testing laboratory. He started his Bell System career in 1921 as a materials engineer on the technical staff of the Bell Telephone Laboratories in New York where he was associated with F. F. Lucas in the development of new high-magnification metallographic studies of alloys used in telephone equipment.

In 1930 he transferred to the Hawthorne Works of Western Electric Co. in charge of metallographic development of ferrous and nonferrous metals used in telephone plants. During World War II, he was on loan from Western Electric as deputy director of the conservation division of the War Production Board.

A member of a long list of technical groups, he has been a national trustee of A.S.T.M. and first chairman of the Committee on Die Cast Metals. He is also a past chairman of the Chicago Chapter and past national trustee of A.S.M.

The 180-cycle Multiductor, a low-cost static frequency converter, permits the use of induction on heating and melting applications where costs were previously prohibitive.

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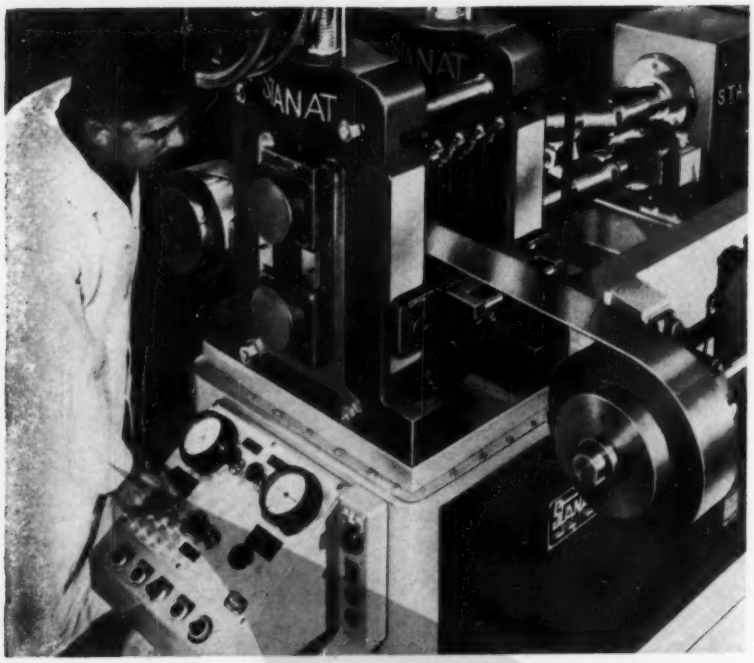
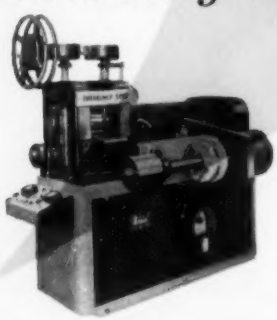
Circle 862 on Page 48-B



ALL PURPOSE ROLLING MILL WITH *Low Cost Reversing* **FEATURE!**



Now! You can have a complete reversing strip mill facility, for less than you ever thought possible. With a Stanat 2-high/4-high combination mill, the two-way strip winding arrangement (as illustrated) is driven from the mill motor. Powerful air clutches provide extremely sensitive control over a wide range of tensions.

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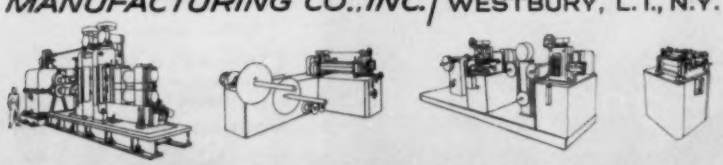

MFR'S OF ROLLING MILLS, GANG SLITTERS, WIRE FLATTENING MILLS, ROLLER LEVELERS AND BULL BLOCKS

Circle 863 on Page 48-B

Personals . . .

Harold P. Weinberg – from chief materials engineer, heading the materials engineering branch of the U. S. Naval Weapons Plant to chief materials engineer for Value Engineering Co., Alexandria, Va.

I. Melville Stein, president, Leeds & Northrup Co., Philadelphia – elected president for 1960 of the Foundation for Instrumentation Education & Research sponsored by the Instrument Society of America. Dr. Stein has been a director of the foundation since its formation four years ago.

Carl H. Smith – from project manager of special and government contracts in the sales engineering department to manager of sales engineering for E. W. Bliss Co., Canton division.

Seymour Rosenbaum – now chief metallurgist for Metallurgical International, Inc., Wallington, N.J. **Ira Friedman** is assistant to the executive vice-president.

Eliot Lee Putnam – now sales representative in Worcester County, Massachusetts, for Hawkridge Bros. Co., Boston and Waterbury, Conn.

Roderick S. O'Conner – from service metallurgist to division manager of quality and process control at the Detroit plant of Jones & Laughlin's Stainless and Strip Div.

Edward H. Perkins, Jr. – from vice-president, general manager to executive vice-president and general manager, Brooks & Perkins, Inc., Detroit.

Henry F. Peters – from market development manager, Lukens Steel Co., to marketing manager for metal products in the pigments department of E. I. du Pont de Nemours and Co., Inc.

Raymond Mohlie – now vice-president and general manager for Engineering Casting, Inc., in Marshall, Mich.

Thomas E. Millsop, president and chief executive officer of National Steel Corp. – to be presented the A.I.M.E. Benjamin F. Fairless Award for 1961 at the Institute's annual meeting in St. Louis at the end of this month.

William C. Schulte, chief metallurgist of Curtiss-Wright Corp.'s Propeller Div. in Caldwell, N. J. – appointed an advisor in mechanical engineering to the board of trustees of Newark College of Engineering.

Lloyd E. Rautiola – now sales engineer for New Jersey and Pennsylvania for the Linde Co., a division of Union Carbide Corp.

Lawrence J. Litalien – from in charge of outside purchasing of castings for Waterbury Farrel Foundry & Machine Co., a division of Textron, Inc., Waterbury, Conn., to purchasing agent for the company.

Robert W. Lindsay, professor of metallurgy, Pennsylvania State University – appointed head of the department of metallurgy, succeeding **Amos J. Shaler**. At the same time **John H. Hoke** and **Earle R. Ryba** were named assistant professors in the department.

R. O. Lane, vice-president in charge of research and development at the Macklin Co., Jackson, Mich. – named an honorary member of Keramos, the national professional fraternity of ceramic engineers, scientists and technologists.

Leon A. Hurwitz – from product manager, precision metals division, Hamilton Watch Co., Lancaster, Pa., to director of the newly established metals and electronics division. **Harry Hovis**, formerly assistant product manager of the precision metals division, was named assistant director for metals in the new division.

Raymond LaFontaine – from staff engineer, West Coast operations, Los Angeles, for Koehler Aircraft Products Co., Dayton, Ohio, to chief engineer, advanced products.

George D. Haley – now supervisor in charge of hard-surfacing rod production for WaiMet Alloys Co., Dearborn, Mich.

Edward M. Grala – from the Lockheed Missiles and Space Div., Sunnyvale, Calif., to staff engineer in the metallurgy division, Brush Beryllium Co., Cleveland.

Robert B. Gordon – now manager, technical operations, of Atomics International, a division of North American Aviation Inc., Canoga Park, Calif.

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COPE WITH THESE CONDITIONS?

*High heat as compared to other copper-base alloys.

AMPCO® metal

What does a copper-base alloy have to do for you? Whatever it is, there's a grade of Ampco metal — or other Ampco alloy — that does the job exactly.

Equally important, you can select the best, most economical form of production — sand casting, centrifugal casting, shell mold, precision casting, forging, fabrication, extrusion, sheet, plate.

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Circle 864 on Page 48-S

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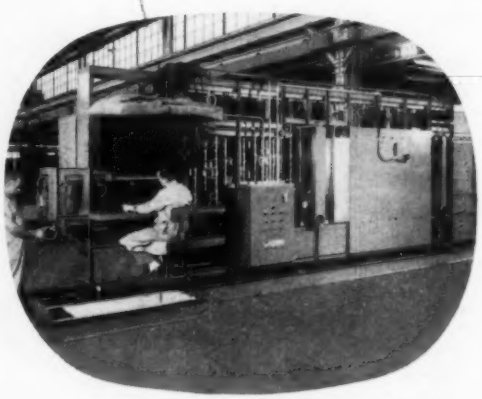
At Magnaflux you find maximum nondestructive testing assistance—in equipment, men and experience-based understanding of your needs and problems. May we put it all at your service—SOON? Phone your local Magnaflux Field Engineer, or write us. Magnaflux Corporation, 7322 W. Lawrence Avenue, Chicago 31, Illinois.



TESTING BEARING CAGES

with ZYGLO fluorescent penetrant. This Zyglo ZA-49, equipped with an endless conveyor, provides mechanized, high volume testing of nonmagnetic parts from ¾" to 10" in diameter. All processing is fully automatic, assuring predetermined control and repeatability of results.

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TEST SYSTEMS

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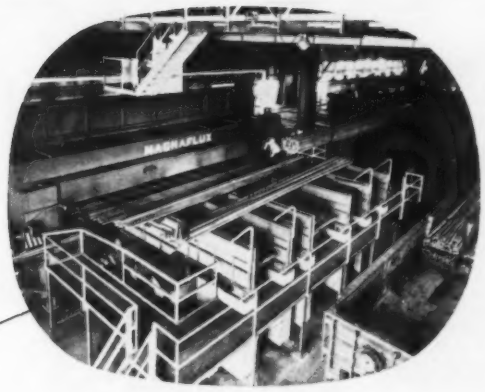
A Few of Thousands of ⋈ Test Installations at Work—Could One of Them Help You?



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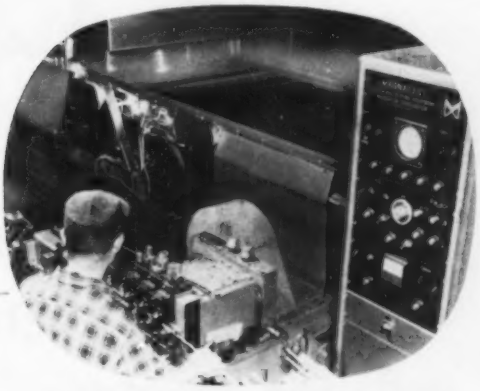
Mechanized, ⋈ engineered inspection and handling provides more control, better quality level, and lower costs from conditioning. MAGNAGLO, electronic eddy current, ZYGLO fluorescent penetrant testing, for billets, tube rounds, welded and seamless tubing and pipe.



TESTING COPPER TUBING ELECTRONICALLY
with MAGNATEST FW-400, for cracks and seams at production speeds. Many kinds of MAGNATEST instruments, hundreds of applications: determining metal properties, defects, characteristics, sorting, etc.

TESTING THICKNESS ULTRASONICALLY
for core shift of castings, or almost any solid material, from .025″ to 3.00″, for thickness, corrosion, etc., from one side only. Portable transistorized SONIZON SO-300 gives instant dial readings, accurate to ±1%. Magnaflux Field Engineer instructs in operation (above).

TESTING JET ENGINE
turbine wheels electronically for serration cracks, with MAGNATEST ED-500G, eddy current instrument. Magnatest units measure relative depth of cracks, electrical conductivity, evaluate metals for all sorts of basic or process-built characteristics.

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of boiler tubes with gamma radiation isotope. X-ray and gamma radiography service available at several locations. Performed by certified technicians and engineers at your plant or at your local ⋈ Commercial Testing Center.

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Circle 865 on Page 48-B

Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Corrosion Engineers Meet in San Francisco

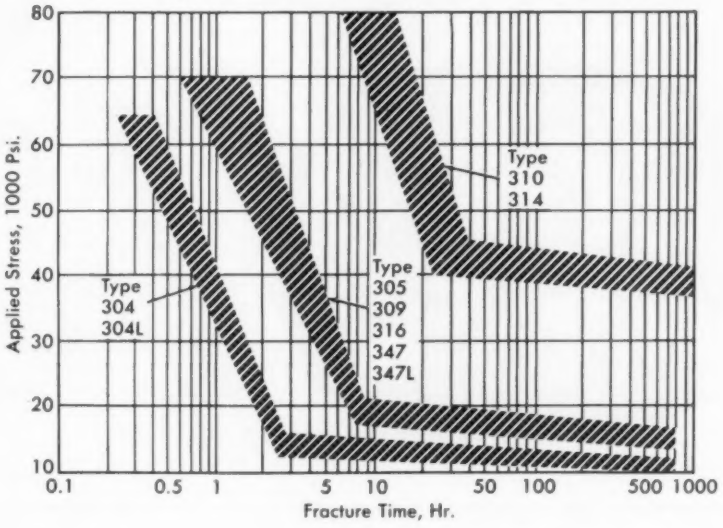
Report on 10th Annual Corrosion Conference of the National Assoc. of Corrosion Engineers, Western Regional Division, October 1960, San Francisco.

LAST FALL, more than 250 corrosion engineers attended the 10th Annual Corrosion Conference (sponsored by the National Assoc. of Corrosion Engineers) to participate in several diversified symposiums of interest to metallurgists. The first of these, a General Corrosion Seminar, began with a discussion of one of the most recent investigations in stress-corrosion cracking of austenitic stainless steels. The speaker, R. A. White (Bechtel Corp.), showed how adjustments in alloy content can reduce tendencies toward stress-corrosion cracking. While additions of carbon and nitrogen are detrimental, nickel and silicon additions tend to lower susceptibility to cracking. It ought to be added that the variations in chromium and nickel content in Types 304 and 304 L were not significant. Furthermore, when carbon and nitrogen were restricted to 0.15%, the high-purity stainless steel did not fail on extended exposure times in boiling 42% magnesium chloride though the specimens were under appreciable stress.

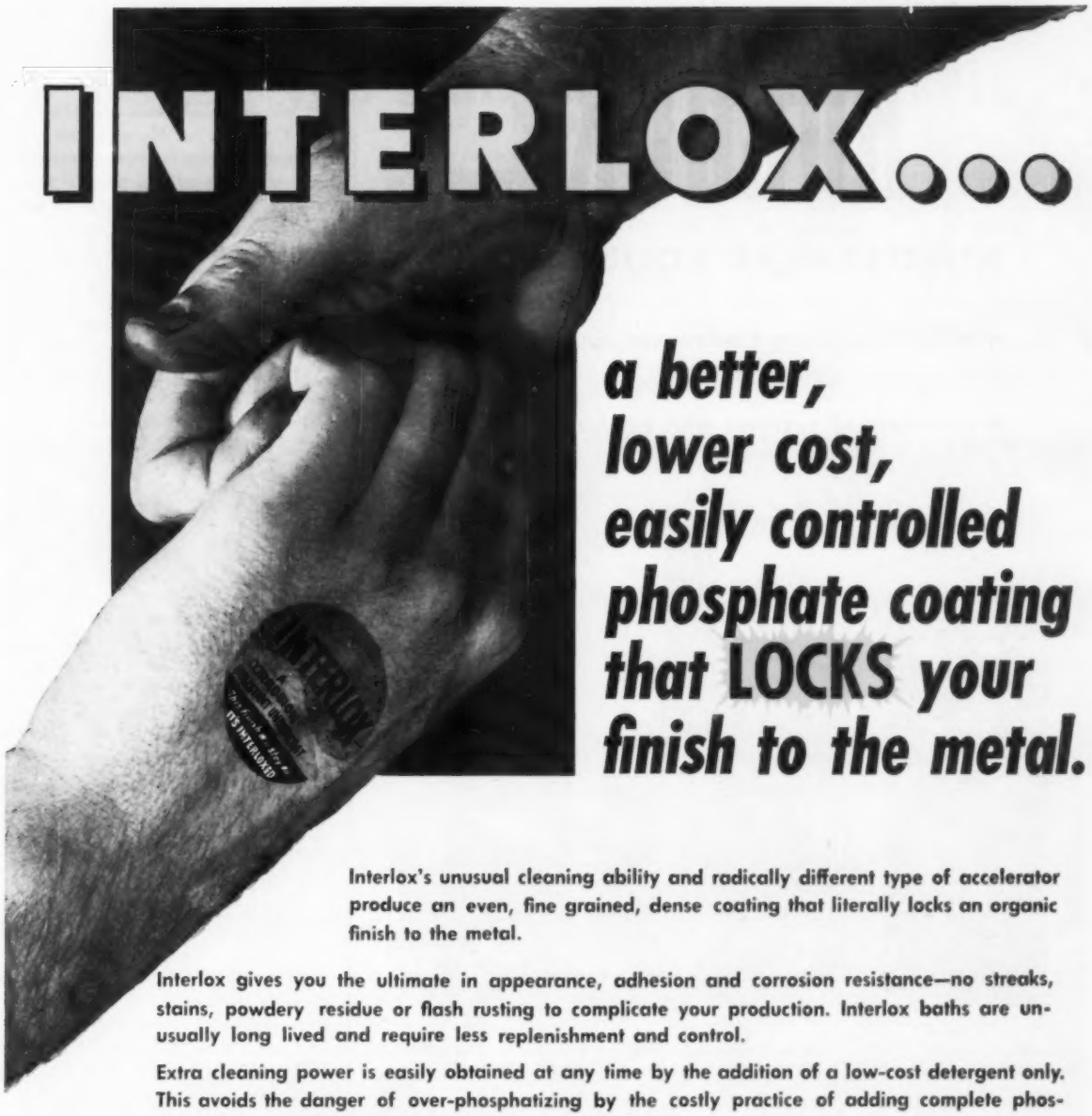
Further work showed that nitrogen, in amounts considerably less than the amount of carbon that is required for failure to occur, will cause stress-corrosion cracking. Studies of the effects of nickel indicated that high-purity alloys do not crack when the nickel content is increased to 20%. However, if the annealed material has been severely cold worked, failures can be made to occur. Silicon additions of 3 to 4% will prevent stress-corrosion cracking in most instances. This effect is especially dependable in vacuum-melted stainless steels. Figure 1 graphically illustrates the effects of varying the applied stresses in austenitic stainless steels upon the time required for stress-corrosion failure.

Stresses which can cause stress-corrosion cracking are not necessarily of the residual type; they may also occur in service. Only the magnitude of the tensile stresses are important in causing stress-corrosion cracking. In short, the prime factors are alloy composition, tensile stress level, corrosive environment, and exposure time. Although carbon, nitrogen, and silicon additions affect the resistance of austenitic stainless steels to stress-corrosion, these elements cannot be controlled properly in commercial stainless steels. For this reason, the stainless steels with higher nickel content (about 20%) should be used to obtain optimum

Fig. 1 – Effect of Stress on Stainless Steels



INTERLOX...



a better, lower cost, easily controlled phosphate coating that LOCKS your finish to the metal.

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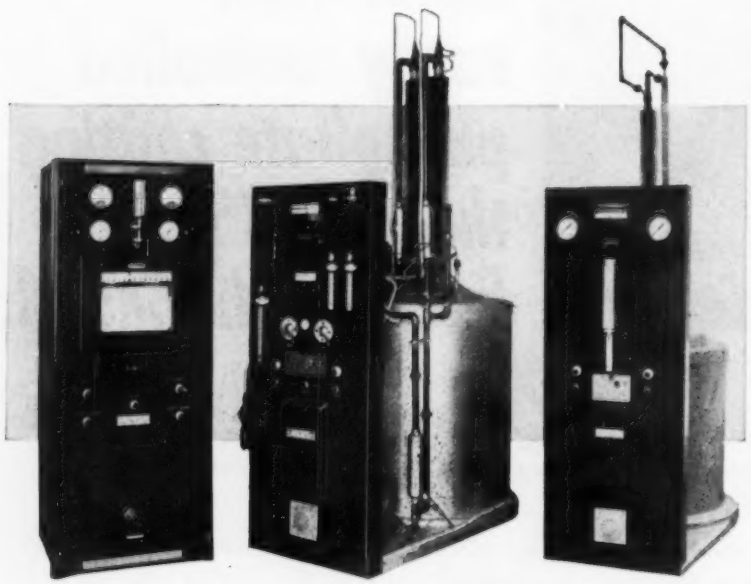

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Circle 867 on Page 48-B

Corrosion . . .

resistance to stress-corrosion cracking. In this discussion the 29% Ni, 20% Cr alloys (or Monel) were recommended where resistance to stress-corrosion cracking is required. Even these alloys, however, have exhibited stress-corrosion cracking in relatively severe environment. Also recommended where high tensile stresses are known to have caused stress-corrosion is a 1600° F. stress-relief heat treatment (if the stainless steel is of an extra low carbon or stabilized grade).

The Petroleum Processing Symposium began with "Sulphur in Flue Gas Corrosion", by P. D. Miller, E. L. White and W. E. Berry (Battelle Memorial Institute). In reviewing the effects of sulphur in flue gas corrosion on carbon steel stacks, the authors stated that severe corrosion can occur if the sulphur dioxide and sulphur trioxide gases react with water or water vapor and condense on the inside walls of the stacks. As little as 0.001% SO_3 in solution can raise the dew point of the gas to 300° F. On the other hand, sulphur dioxide has little effect on the moisture dew point, and little attack was observed on continuous heating at 600° F. Severe SO_2 attack does occur, however, with continuous condensation at 80° F., or upon thermal cycling between 80 and 600° F.

The paper "Corrosion Resistance of Iron-Aluminum Alloys in Petroleum Refinery Operations", by G. R. Prescott and R. B. Setterland (C. F. Braun & Co.) was of great interest from a metallurgical standpoint. The addition of aluminum to high-chromium alloy steels markedly improves their resistance to hydrogen sulphide and oil-ash corrosion. However, the transition to commercial iron-aluminum-chromium alloys in petroleum operations has been delayed by difficulties in producing ductile wrought products of these alloys.

Adding aluminum to low-carbon iron increases the strength, but reduces the elongation sharply (Fig. 2). Though alloys with up to 5% Al can be cold worked and those with 5 to 16% Al can be hot worked, alloys with above 16% Al cannot be hot worked but must be cast and ground into usable configurations.

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Corrosion . . .

However, 3% Mo added to the 16% Al alloy significantly improves high-temperature properties. "Alphenol", a 16% Al alloy, and "Thermenol", a 16% Al, 3% Mo alloy, have been hot rolled at 1070° F.

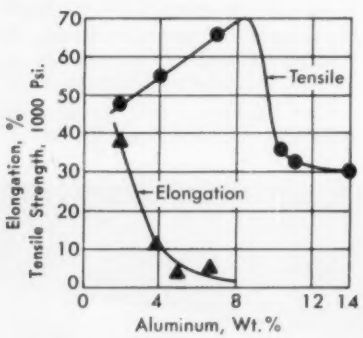

Fig. 2 – Mechanical Properties of Iron-Aluminum Alloys

With more than 8% Al, iron-aluminum alloys show high oxidation resistance at temperatures up to 1800° F., and with aluminum contents of 10% and above, these alloys have excellent oxidation resistance even up to 2370° F. Alloys of iron, chromium, and aluminum also had good corrosion resistance.

Because of accelerated research programs currently underway, iron-aluminum and iron-chromium-aluminum alloys are now being considered for compressors, aircraft and automobile engines, furnaces, plant processing equipment and other applications where oxidation resistance is needed.

The Nuclear and Missile Symposium consisted of three papers, only one of which had some metallurgical interest. The paper "Corrosion of Nickel-Base Alloys in High-Temperature Nitrogen Environments", by G. W. Titus and J. S. Brunhouse (Aerojet-General Nucleonics), discussed the need for an alloy showing good corrosion resistance to 99.5% nitrogen and 0.5% oxygen gas along with reasonable mechanical strength at 1750° F. Such an alloy was required for cladding fuel elements of a gas-cooled nuclear reactor, because of the need for fuel element life up to 10,000 hr.

Six alloys, Inconel, Inconel X, Inconel 702, Hastelloy X, Hastelloy R-235, and Inor 8, were selected for testing under these corrosive environments and temperatures. During the program, researchers determined stress-rupture strengths (at 1750° F. for 50 hr.), creep (1000 hr., 2000 psi., 1750° F.), and corrosion rate (in slowly flowing 99.5% nitrogen, 0.5% oxygen gas and in air, for 1000 hr. at 1750° F.).

As a result of these tests, Hastelloy X, since it showed the best overall properties for service, was designated as the reference alloy for design calculations and further evaluation. Inconel and Inconel 702 were next best, although they were somewhat less favorable than Hastelloy.

The Water Treatment and Water Inhibition Symposium consisted of three papers. First, E. F. Duffek (Stanford Research Institute), presented "The Use of Inorganic Inhibitors for Corrosion Control in Water Treatment Systems". In covering chromate and phosphate-type inhibitors, he explained their functions in water treatment systems. Inhibitors, according to him, are divided into two classes. Chromates and nitrates are oxidizing anodic inhibitors, and phosphates, carbonates, hydroxides, and silicates are nonoxidizing anodic inhibitors (though phosphates may also show the characteristics of cathodic inhibitors).

Concerning oxidizing inhibitors, the mechanism responsible for the protection and passivity offered by chromates has not been definitely established as yet. Two general theories exist, however. In one, weak points in the protective film on the steel surface are "plugged" by a precipitated mixture of hydrated ferric and chromic oxides. (In other words, pores are filled in the protective coating.) The other theory postulates that the chromates are "chemisorbed" on the metal surface, resulting in a mutual sharing of electrons between the metal and the chromate ion. This reduces the chemical activity of the steel surface and minimizes corrosion.

The invisible protective film produced on iron or steel by nitrites is "cubic iron oxide". Ammonia, formed as the cathodic reaction, is also believed to work as a corrosion inhibitor. In this way, steels are protected against corrosion by using nitrites as inhibitors.

As for nonoxidizing inhibitors, they produce thin films on the steel

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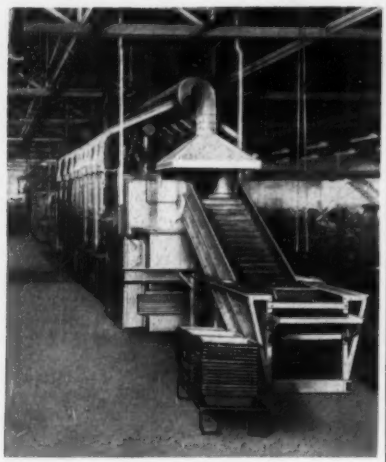

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Circle 925 on Page 48-B

Corrosion . . .

surface, which are invisible, but protect the surface by film continuity. For example in water systems, a thin calcium carbonate scale can be formed on the metal surface by adjusting the chemical balance of the water so it maintains a slightly supersaturated solution of calcium carbonate. With iron immersed in an air-saturated phosphate solution, the protective film formed consists almost entirely of "cubic oxide" with "plugs" of $FePO_4 \cdot 2H_2O$ embedded in the oxide matrix. The mechanism for this protective coating buildup appears to be the formation of ferrous ions through the pores in the existing oxide film These ferrous ions are then changed by reaction with oxygen to ferric ions which are then precipitated at the metal surface as phosphates

The second paper, presented by R. A. Powers (Union Carbide Consumer Product Co.), was entitled "Organic Material as Corrosion Inhibitors in Aqueous Media". According to the author, organic materials function as corrosion inhibitors by several mechanisms. In an aqueous medium, an adsorbed film of an organic phase is built up on a metal surface. This surface phase may function simply as a diffusion or isolating barrier between the metal and its environment, or it may affect the electrochemical kinetics of one or more of the steps in the corrosion reaction. The mechanisms by which these films inhibit corrosion are as follows (assuming that an organic phase has formed on a metal surface). In one, the "simple physical barrier", the organic phase forms a water-repellant surface which isolates the metal from its environment and keeps oxygen and other corroding agents away from the metal. If an "electrical barrier" is involved, the organic phase imposes a high electrical resistance to the normal electrochemical paths of corrosion. There may also be a "kinetic factor": Organic films on metal surfaces are believed to interfere with the various kinetic processes involved in corrosion. The important fact to be kept in mind is that certain organic materials function by converting oxygen from a corrosion accelerator to a passivating or corrosion inhibiting agent.

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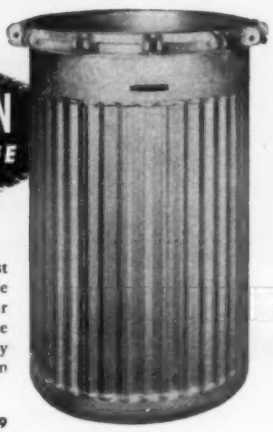

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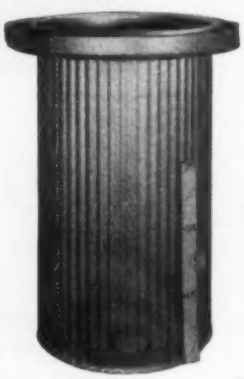

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Circle 924 on Page 48-B

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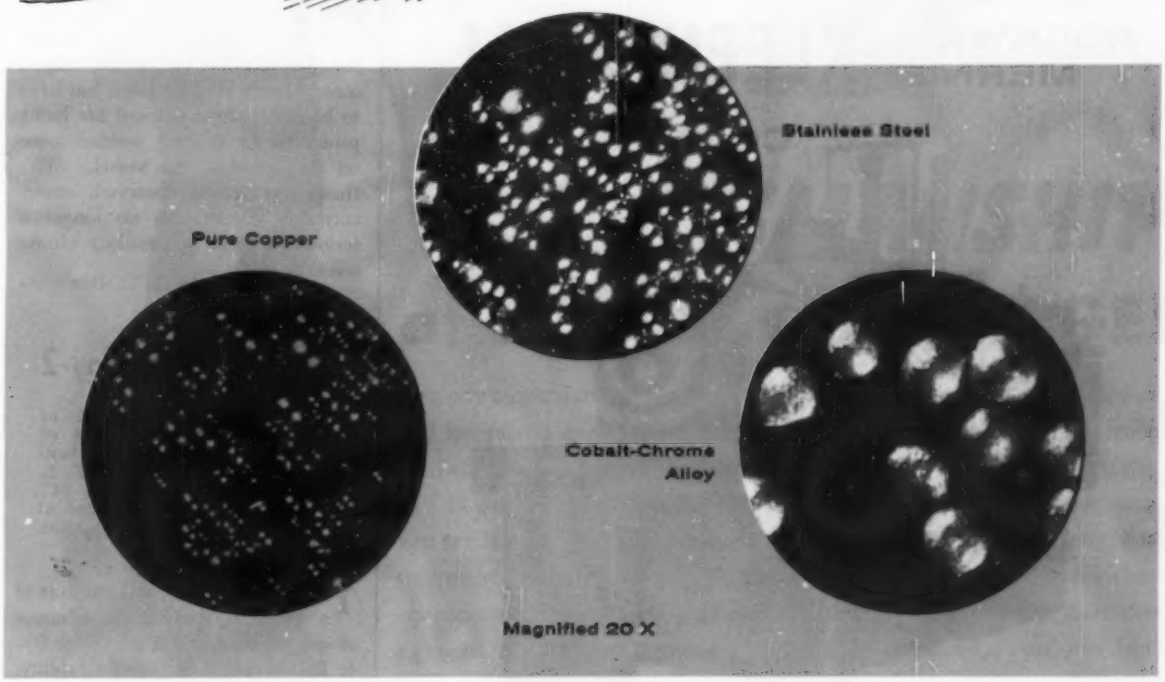

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Circle 881 on Page 48-B

Corrosion . . .

The Chemical Industries Symposium was comprised of three technical papers, the first of which was "Problems in Pilot-Plant Corrosion Testing". Presented by R. S. Treseder (Shell Development Co.), this paper discussed problems involved in obtaining reliable corrosion data from a pilot-plant testing program. According to him, two main factors must be carefully studied when evaluating pilot-plant data: Variations in operating conditions between the pilot plant and the full-scale plant, and effects of differences in surface-to-volume ratio. "Stress-Corrosion Cracking of Carbon Steel in Ammonium Nitrate Solutions", by E. H. Edwards, R. L. Piehl and A. E. Barta (California Spray-Chemical Corp.), covered an investigation into failures in tanks which held nitrate fertilizers. These failures were the result of stress-corrosion cracking of an intergranular nature, similar in appearance to cracking caused by sodium hydroxide. To remedy the situation, they recommended that all new vessels going into service be stress-relieved. This would remove, or minimize, the stresses in the vessel, which are required along with the corrosive medium to initiate and promote stress-corrosion cracking failures.

Consideration was also given to coating the inside surfaces of these vessels with protective films. By applying polyester and epoxy coatings only on the welded areas, promising results have been obtained; however, insufficient time has elapsed for a complete evaluation.

As a result of this investigation, most of the new steel storage vessels for this service are stress-relieved after construction. Vessels too large to be easily stress-relieved are being protected by coating welded areas on the inside of the vessel. With these precautions observed, stress-corrosion cracking is no longer a serious problem in handling nitrate solutions.

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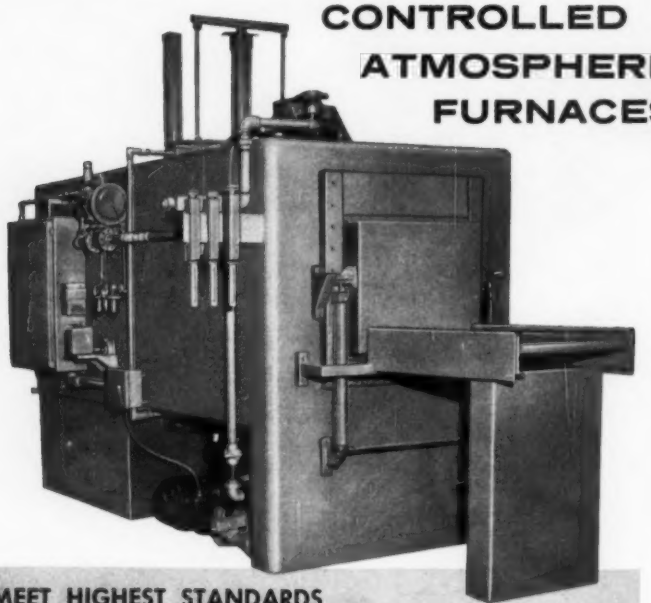

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Circle 882 on Page 49-B

Oxygen in Zircaloy-2

Digest of "The Effect of Oxygen on the Properties of Zircaloy-2", by L. S. Rubenstein, J. G. Goodwin and F. L. Shubert. ● Preprint No. 247, 1961. Paper to be presented at the National Metal Congress, October 1961, Detroit.

THIS PAPER PRESENTS the results of a systematic study of the influence of oxygen content (in the range 900 to 10,000 ppm.) on the fabricability, strength and corrosion characteristics of Zircaloy-2. Alloys were prepared by adding zirconium dioxide to sponge zirconium compacts; these mixes were then double arc melted to obtain 5-in. diameter ingots. Next, ingot forging at 1850° F. was followed by hot rolling at 1550° F. However, alloys containing more than 5000 ppm. oxygen could not be fabricated by this procedure. Instead they had to be forged at 1900° F. and rolled at 1825° F.

Hot hardness tests, illustrated in Fig. 1, reveal the pronounced hardening associated with the addition of oxygen to Zircaloy-2. Hardness increased in proportion to the square root of the oxygen content, the hardening effect of oxygen being

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Circle 883 on Page 48-B

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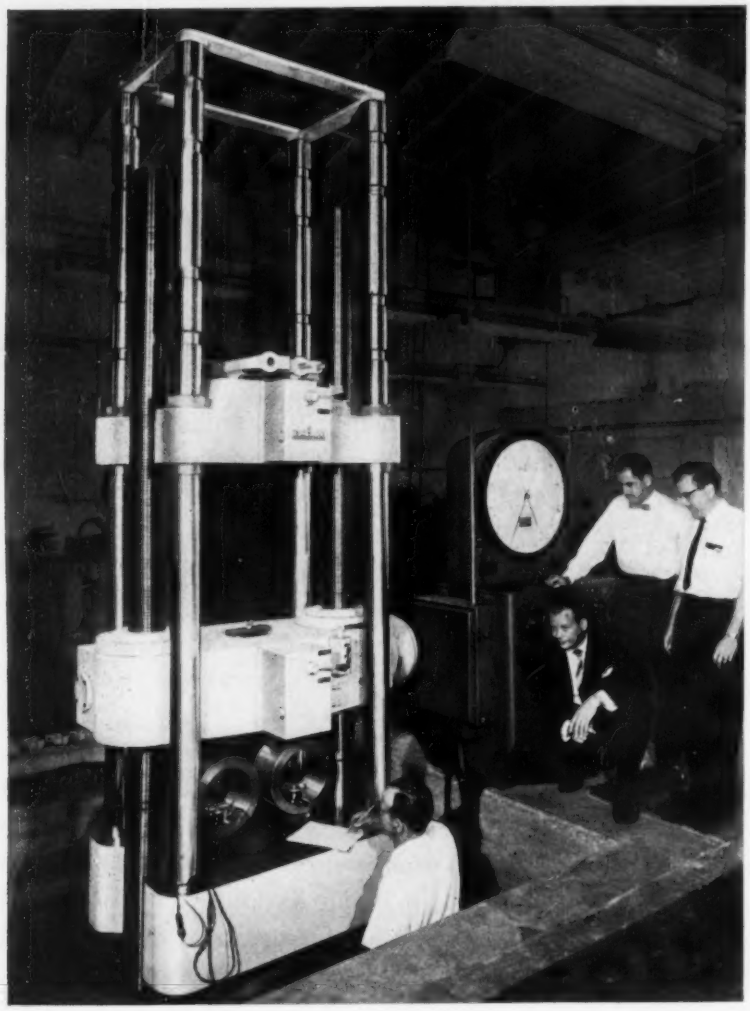

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Circle 884 on Page 48-B

Oxygen in Zircaloy-2 . . .

retained up to about 932° F. However, at higher temperatures, hardness was essentially independent of oxygen content. Heat treatment – furnace or air cooling from 1850° F. or 1380° F. – did not affect hardness. The strengthening effect of

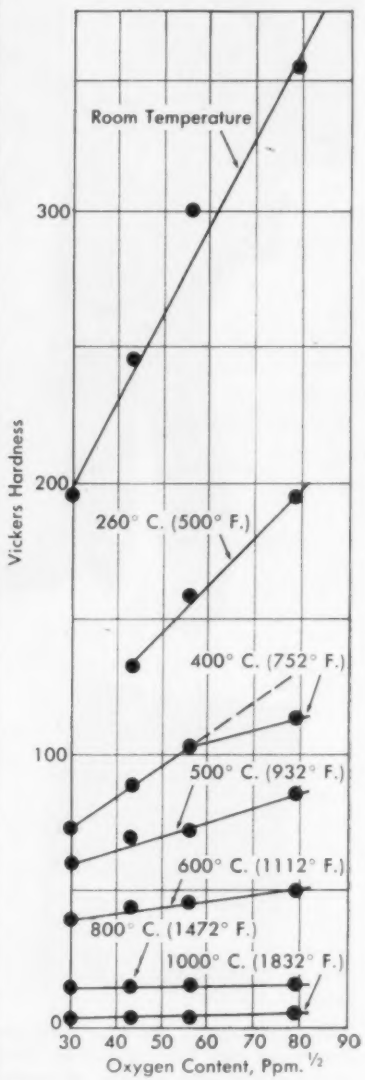
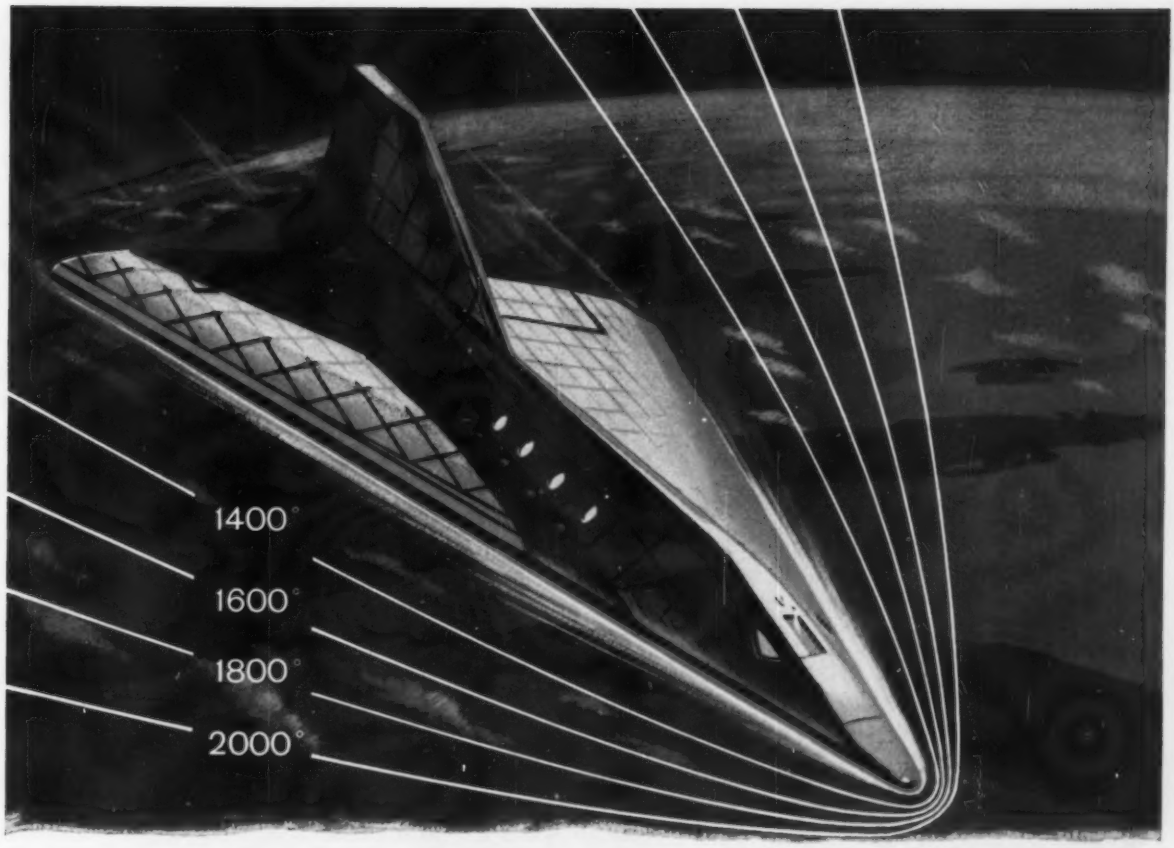


Fig. 1 – Hot Hardness of Zircaloy-2 Alloys Containing Different Amounts of Oxygen

oxygen also was reflected in increased tensile and yield strengths and loss in ductility.

Oxygen lowered significantly the resistance of Zircaloy-2 to corrosion by steam at 750° F. or water at



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Circle 885 on Page 48-S

Oxygen in Zircaloy-2 . . .

680° F. Irrespective of heat treatment, oxygen increased the corrosion rate of Zircaloy-2, and samples furnace cooled from 1850° F. exhibited the lowest corrosion resistance. Oxygen levels above 2000 ppm. consistently yielded corrosion rates above acceptable limits which are currently specified.

R. H. HEHEMANN

Direct Iron Reduction by Carbon

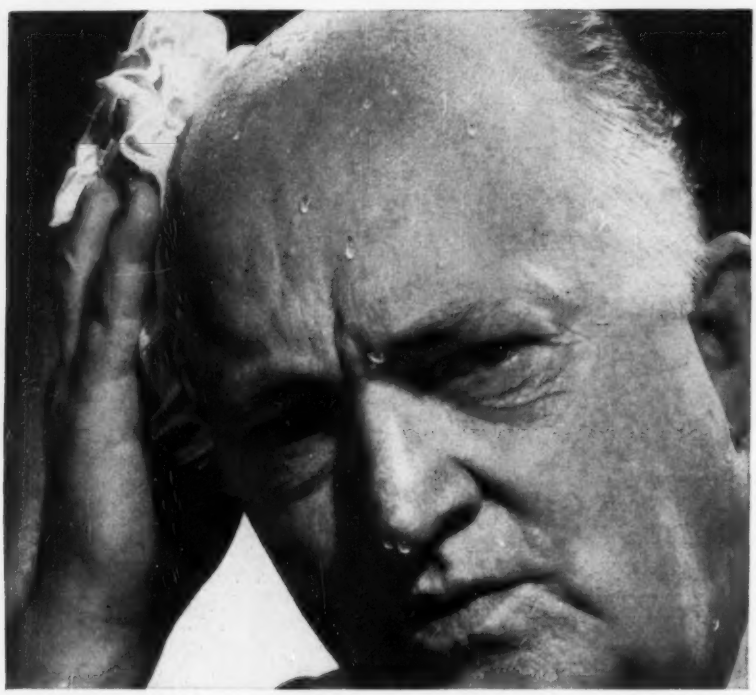
Digest of "Direct Reduction of Ferric Oxide by Solid Carbon in Vacuum", by T. S. YUN. Preprint No. 251, 1961. Paper to be presented at the National Metal Congress, October 1961, Detroit.

CURRENTLY, THERE IS MUCH INTEREST in new techniques of direct reduction of iron ores. To develop such techniques, of course, the mechanisms and kinetics of the reduction processes must be understood. Two different reduction processes, direct and indirect, occur within the blast furnace. For direct reduction, carbon (as coke) reacts directly with iron oxide to form metallic iron, carbon monoxide and some carbon dioxide. Indirect reduction involves carbon monoxide, formed by interaction of coke with the air blast, reacting with iron oxide to form metallic iron and carbon dioxide. This carbon dioxide may subsequently react with excess carbon to regenerate carbon monoxide.

Indirect reduction has been the subject of many experimental investigations, and data are available to characterize both its equilibrium and kinetic behavior. In contrast there have been few studies of direct reduction of iron oxides with solid carbon. This can be explained, if not justified, by two factors: the greater significance ascribed to indirect reduction in normal blast furnace operation, and the comparatively greater experimental difficulties encountered in studying the solid-solid reduction reaction. These difficulties are compounded by the need to remove rapidly the gaseous products of the reaction, carbon monoxide and carbon dioxide, if one is to eliminate the effect of indirect reduction from the study.

For this research, a vacuum thermobalance was used. Equal weights of graphite and virtually pure (99.98%) ferric oxide were thoroughly mixed and charged in a silica crucible in the thermobalance. Next, the system was outgassed at room temperature, and the sample was then rapidly heated to reaction temperature. Products were exhausted through one of two trap lines, carbon dioxide being frozen out in a constant volume liquid air trap. Continuous decrease of sample weight was recorded by the thermobalance. After a definite time interval, the exhaust stream was diverted to the second trap line, and the amount of CO_2 trapped during the previous time increment was determined by constant volume pressure measurements after removal of the liquid air container. Similar measurements were repeated at regular intervals throughout the reaction period.

The data were analyzed to eval-



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Circle 886 on Page 48-B

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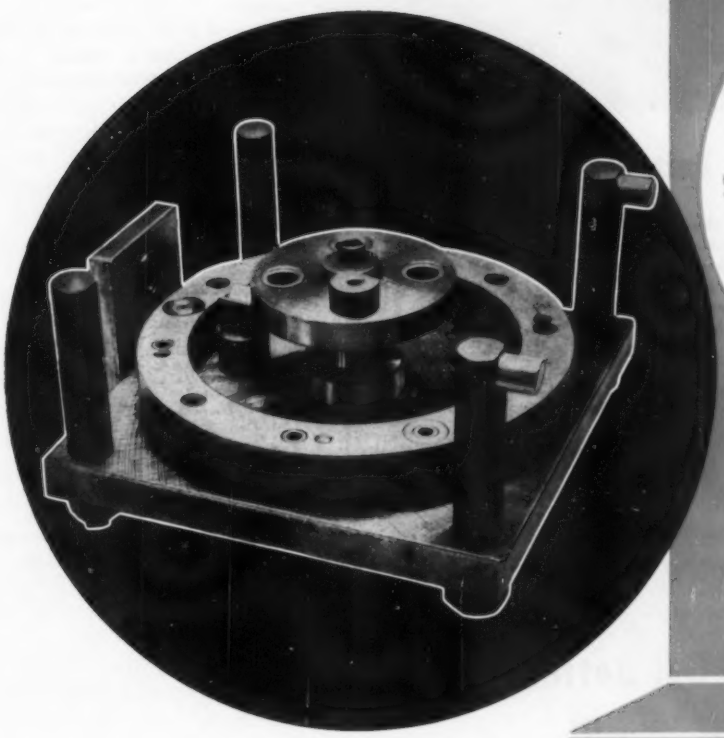

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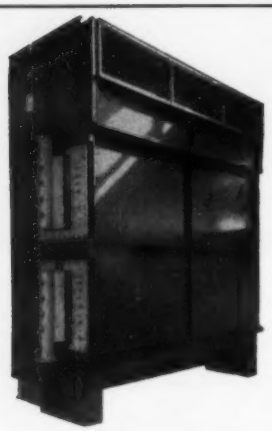
Circle 889 on Page 48-8



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Circle 888 on Page 48-8

Direct Reduction . . .

uate the effects of reaction temperature and time upon the incremental and cumulative degree of reduction, results being shown in Fig. 1 and 2. As is shown, the degree of reduction is markedly affected by temperature. Reduction of ferric oxide to metallic iron by solid-solid is possible only above 900° C. (1650° F.) although complete reduction was not obtained at this temperature within the 20-hr. runs used in this study. Almost complete reduction was obtained in 8 hr. at 1000° C. (1830° F.) and in 2 hr. at 1100° C. (2280° F.).

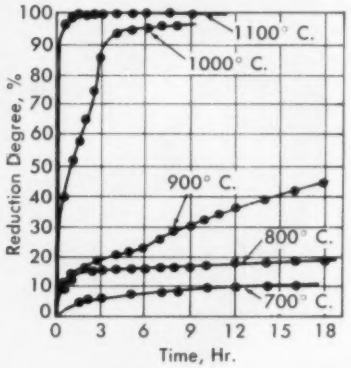

Fig. 1 – Reduction Degree Curves at Various Temperatures

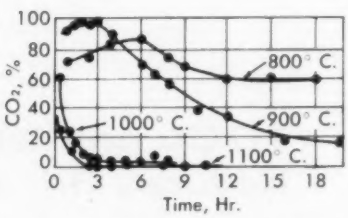

Fig. 2 – Change of Gas Consumption During Direct Reduction Between 800 and 1100° C.

When gaseous products of this reduction reaction were analyzed, both CO and CO_2 were present in the initial stages of direct reduction. The CO_2 content appeared to achieve a maximum value as a function of time, this maximum point occurring at shorter times with higher temperature. Although the author cites the possibility of relating gas composition to the type of oxide surface involved, such a relationship is not obvious from these results.

The data were analyzed to determine the validity of two proposed

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Some things change drastically in fifty years; several are shown on this page. Other things change, too, but less noticeably — heat treatment of metals for example. Companies grow and prosper by helping to cause these changes and advancements. The Park Chemical Company started the manufacture of an improved carburizing compound for steel parts in 1911. Through the years they have developed better carburizing compounds, water-soluble and deep-case liquid carburizing salts, neutral salts and methods to maintain their neutrality, aluminum and magnesium brazing salts, quenching and tempering salts and oils, and protective coatings. With all their growth and change, one thing remains the same: a desire to help the heat treater with his problems.

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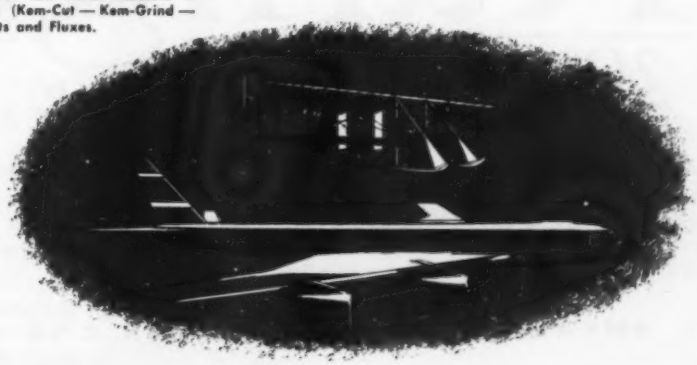

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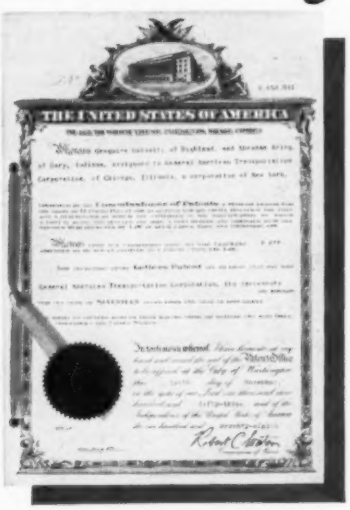

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Circle 891 on Page 48-B

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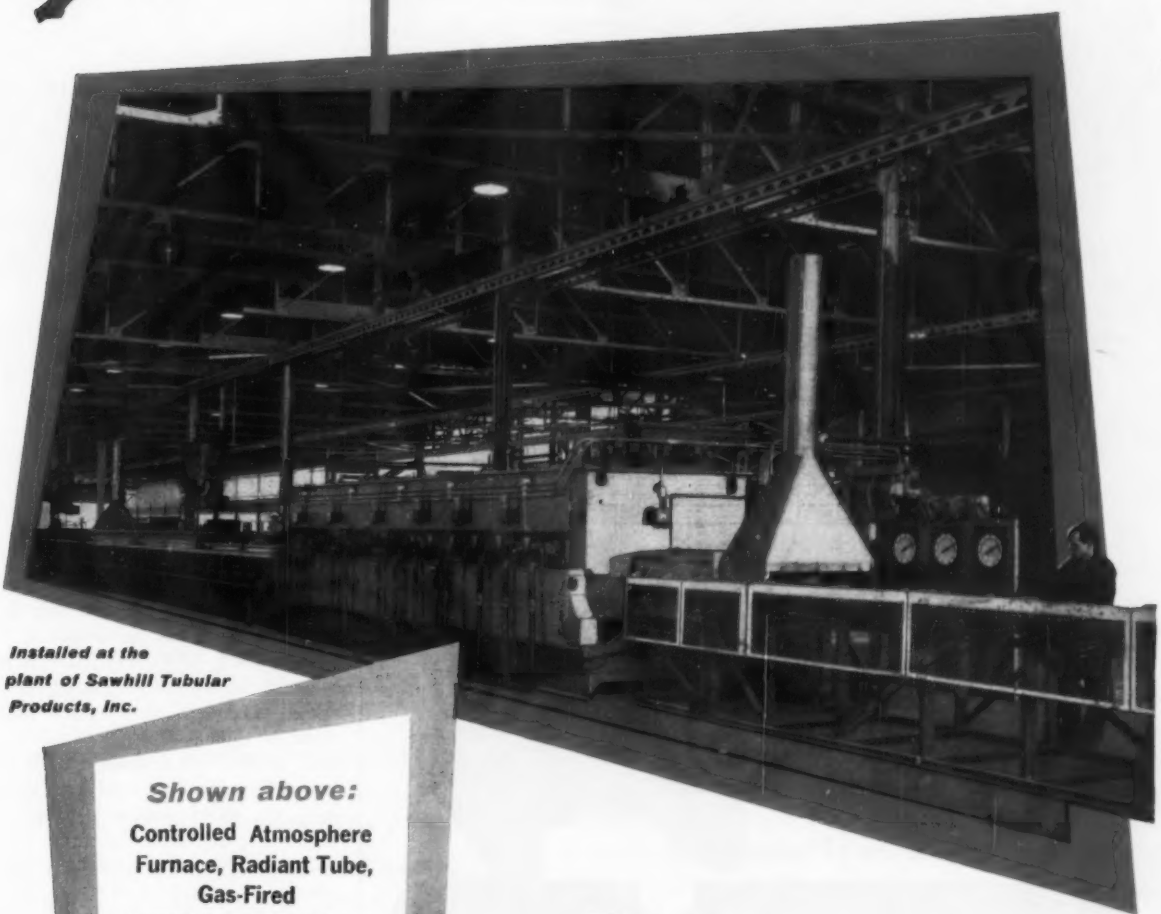

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Circle 892 on Page 48-B

Direct Reduction . . .

diffusion-controlled mechanisms for the direct reduction process. Since the results do not fit the time dependent curve predicted from a theoretical analysis of a carbon diffusion-controlled mechanism, the author rejects this hypothesis.

The data qualitatively fit a mechanism in which the diffusion of iron atoms through the iron oxide is treated as the controlling step. The reduction proceeds by the following sequence:

$$Fe_2O_3 \rightarrow Fe_3O_4 \rightarrow FeO \rightarrow Fe$$

with each new phase being nucleated at the surface and growing inward by diffusion of iron atoms moving under the influence of the resulting concentration gradient. The intermediate minimums in the rate of reduction (inflection points on Fig. 2) observed at 900° C. (1650° F.) and 1000° C. (1830° F.) are explained as corresponding to the achievement of maximum iron concentration in a wüstite phase. In other words, there is a condition of minimum anion vacancies, with a resultant minimum in the diffusion rate of iron. It is unfortunate that no metallographic studies were included to confirm these speculations.

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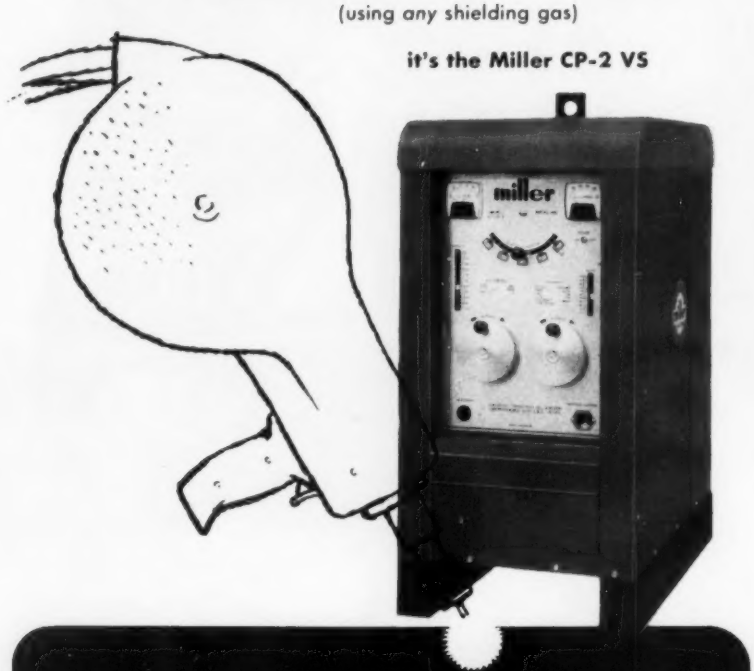

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Circle 893 on Page 48-B

Creep of Aluminum

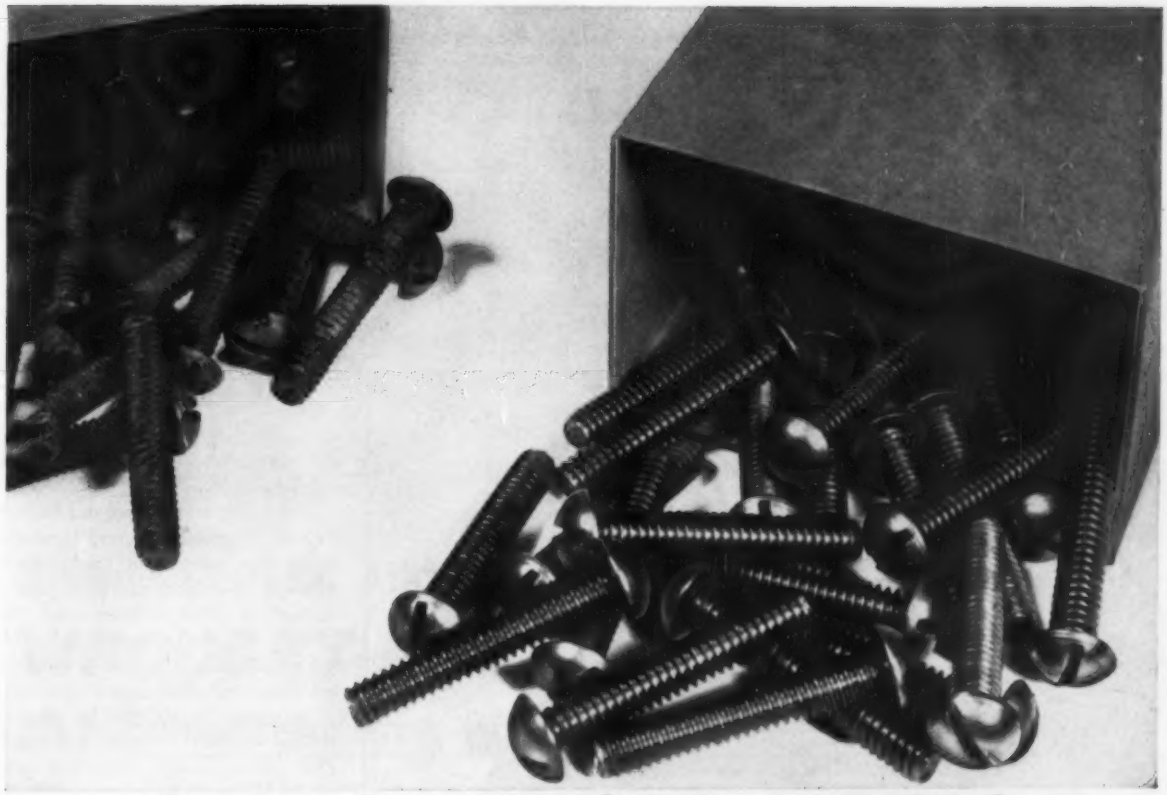
Digest of "Effect of Stress Decreases on the Creep of Aluminum in the Dislocation Climb Region", by L. Raymond, W. D. Ludemann and J. E. Dorn. Preprint No. 245, 1961. Paper to be presented at the National Metal Congress, October 1961, Detroit.

The authors have considered the effect of stress and dislocation substructure on the creep rate of high-purity aluminum at temperatures above one-half the absolute melting temperature of aluminum. This is the temperature range where creep is controlled by the dislocation-climb mechanism. Actual test temperatures are not stated in the text; however, the figures indicate that testing was done at 510 and 555° K.

Creep tests were performed in a molten KNO_3-KNO_2 salt bath at a constant stress. For testing, annealed specimens were loaded to a stress of 1300 psi., while permitting 0.02 or 0.15 true strain to occur. Since straining produced two substructures which contained different dislocation densities, the stress was reduced when the specimens had reached the desired true strain. The creep rate was again observed until the uniform creep rate typical of second stage creep was obtained.

The creep behavior following the stress reduction of specimens with 0.02 true strain indicated the dislocation density needed to produce second stage creep at the new stress level had not yet been reached for stresses above 650 psi. Therefore, the creep rate decreased with time (first stage creep) as the dislocation structure developed until a uniform substructure was obtained producing a constant creep rate (second stage creep).

The 0.15 true strain occurred in the second stage of creep. After reducing the stress, creep behavior showed that the dislocation density was greater than that required to



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Circle 894 on Page 48-B

Creep of Aluminum . . .

produce second stage creep at the new stress level. This resulted in a back pressure of the dislocation field which produced dislocation movement counter to the applied stress. Back pressure is different for the different dislocation orientations. This results in the locking dislocations adjusting their density to the new stress level more slowly than the glide dislocations. In these instances, the creep rate decreased to a minimum uniform rate controlled by the residual barrier structure, and then increased to a rate determined by the second stress level and the new substructure.

In both of the above instances the secondary creep rate at the reduced stress level was controlled by the stress. Primary creep behavior was controlled by the residual structure created at the first stress level and the reduced stress.

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Circle 895 on Page 48-S

Graphite Spheres in Ductile Cast Iron

Digest of "A Quantitative Metallographic Analysis of Graphite Sphere Size in Ductile Cast Iron", by J. H. Brophy and M. J. Sinnot. Preprint No. 239, 1961. Paper to be presented at the National Metal Congress, October 1961, Detroit.

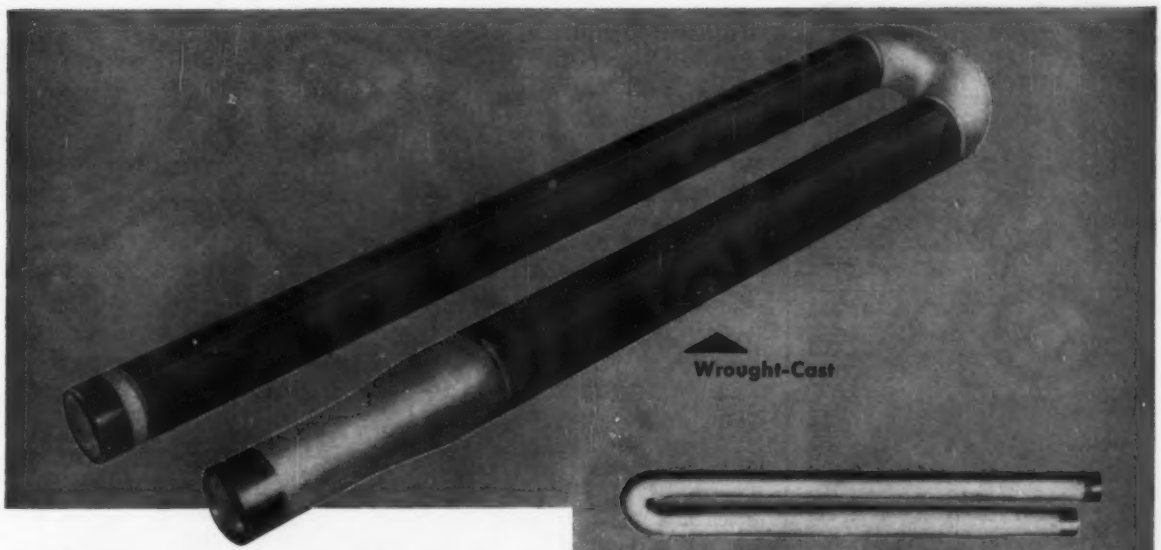
THIS PAPER ILLUSTRATES a technique that can be used to determine the sphere size of graphite in ductile cast iron. The authors were interested in determining whether such spheres were uniform or were different sizes when the size of casting varied.

According to the Lord and Willis* method, originally devised to investigate the size of air bubbles in concrete, if a random line is passed through a solid sample, and the lengths of the intersections with spherical inclusions (chord lengths) are measured, the number of chords of a given length can be plotted against the total length measured. This chord length frequency plot would be linear for a uniform single sphere size; it would pass through the origin and reach a maximum number at a chord length equal to the sphere diameter. Furthermore, several sizes of spheres would yield a frequency plot which was a summation of the linear plots for each size present. In the end, a continuous distribution of sizes would yield a continuous frequency curve.

Lord and Willis presented a graphical method for obtaining the true distribution of sphere sizes actually present from the observed frequency plot of intercepted chord lengths. From this data such properties of the sphere size distribution as the mean area diameter, diameter having the mean volume as well as the volume fraction could also be determined.

In their work Brophy and Sinnott verified the Lord and Willis method by using three samples of a known distribution of sphere sizes. The resulting chord length frequency plots in each instance had the shape predicted, and each distribution

*"Calculation of Air Bubble Size Distribution From Results of a Rosiwal Traverse of Aerated Concrete", by G. W. Lord and T. F. Willis, *A.S.T.M. Bulletin*, No. 177, October 1951, p. 57.



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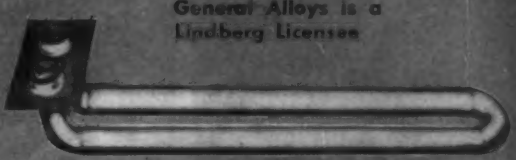

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Circle 896 on Page 48-B

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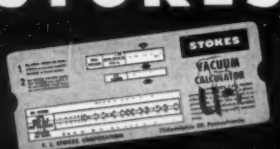

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Circle 897 on Page 48-B

Graphite Spheres . . .

yielded the correct size and volume fraction of each size to within about 10%. In the quantitative examination (with a microscope equipped with crosshairs and a movable stage), the data required were the chord lengths intersected on graphite spheroids by random lines passing through the solid and the total length of the lines.

The first heat of ductile iron was cast in a 3-in. keel block, and heat treated at 1400° F. (760° C.) for 6 hr. The second heat was cast in 1, ½, and ¼-in. keel blocks; the blocks were then annealed at 1675° F. (915° C.) for 3 hr., furnace cooled to 1300° F. (705° C.) and held 5 hr. The third heat was cast in the same three section sizes, but the 1650° F. heat treatment was extended to 12 hr.

Figure 1 is a sample plot of the chord length frequency data for the specimen from the ½-in. section of the third heat. Figure 2 shows a sample plot of the calculated sphere size distribution.

It was found that the maximum graphite sphere size present in a casting varies with the casting section thickness. In general, the largest spheres are found in the

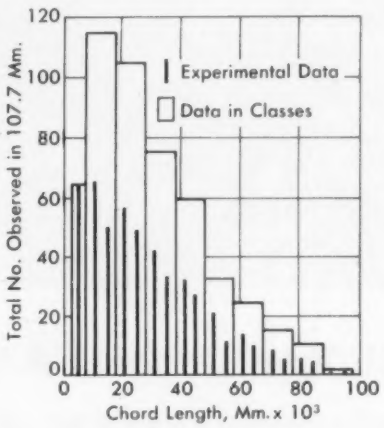

Fig. 1 — Chord Length Frequency Plot for the Sample From ½-In. Section of the Third Ductile Iron Heat

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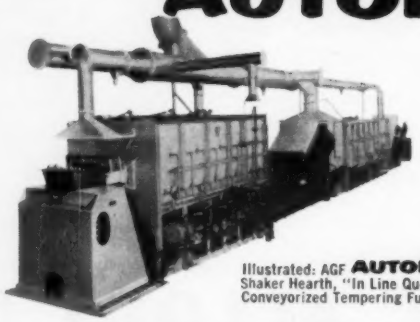

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Circle 898 on Page 48-B

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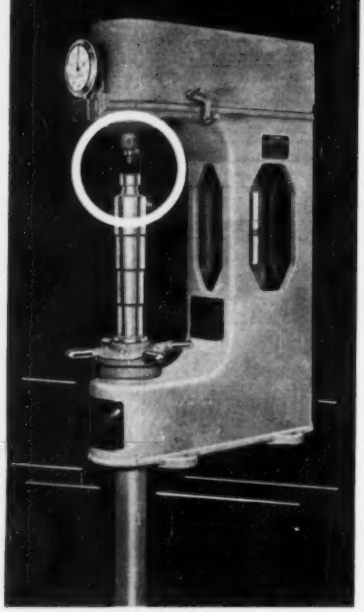

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Missile-Age Accuracy

Circle 900 on Page 48-B

Graphite Spheres . . .

thicker sections. Within a given casting section thickness, there is a continuous distribution of graphite sphere sizes present, so that there are a large number of small spheres and relatively few of the maximum diameter. The average sphere diameter in a given section is considerably smaller than the diameter of the largest spheres present; the average graphite sphere size is essentially independent of casting thickness.

S. L. GERTSMAN

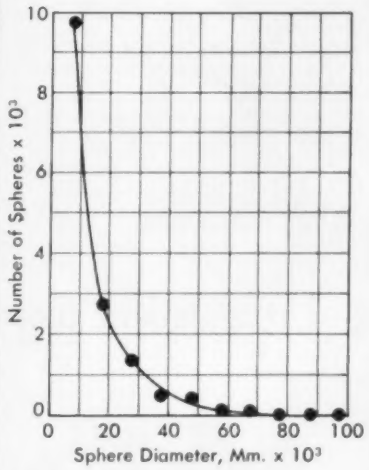

Fig. 2 – Calculated Sphere Size Distribution for Sample From ½-In. Section of the Third Ductile Iron Heat

Deforming Single Crystals

Digest of "Shear Deformation of Magnesium and Zinc Crystals", by W. L. Phillips, Jr. ● Reprint No. 244, 1961. Paper to be presented at the National Metal Congress, October 1961, Detroit.

EXPERIMENTS OF THE TYPE described in this study were previously performed by Parker, Edwards and Washburn. Their results on stress-strain curves of zinc single crystals which were extended in direct shear at various temperatures showed complete agreement of the

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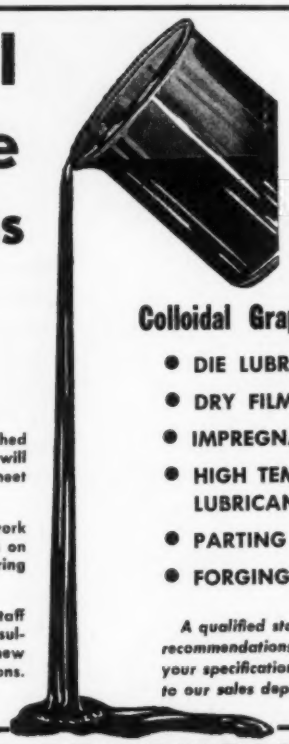

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Circle 901 on Page 48-B

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—Elco Corporation, Philadelphia, Pa.

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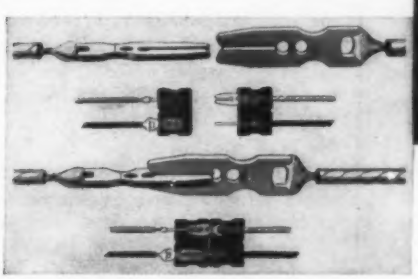

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Circle 902 on Page 48-B

Deforming Crystals . . .

critical resolved shear stress and shear strengthening curves with those obtained in tension. They also obtained complete recovery upon heating specimens after a test run; this permitted multiple tests on a given crystal by annealing and reversing shear direction after each test. Washburn and Parker found that strain hardening in zinc in simple shear was directional. Reversed shearing without intermediate annealing caused plastic flow to begin at a stress lower than that for onset of slip in a given direction. The level of the stress-strain curve was lowered appreciably by the reversal. Equal hardening of the latent slip direction at 60 and 120° to the active slip direction also occurred, with the amount of this hardening increasing as a function of strain in the first direction.

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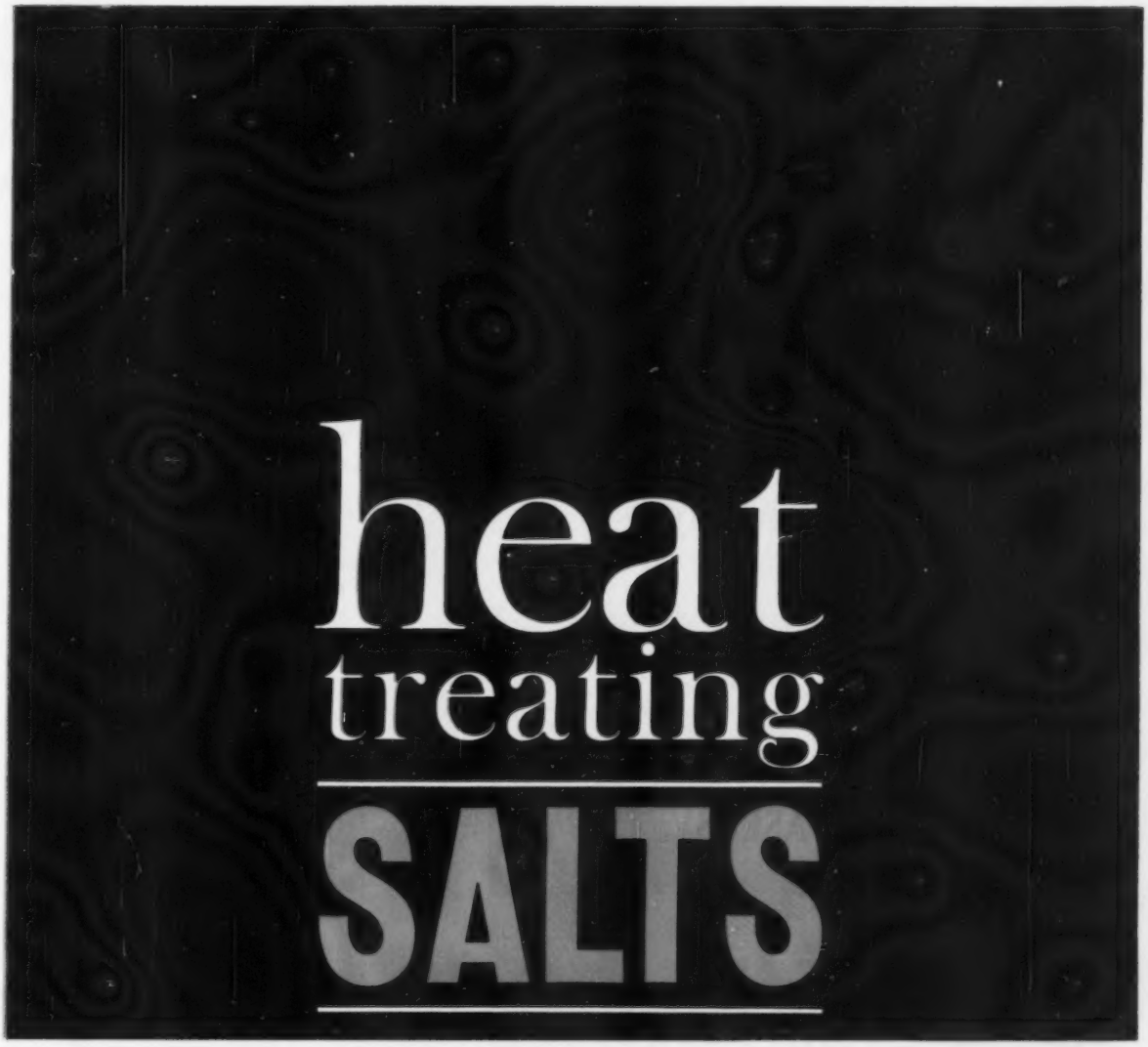
Circle 903 on Page 48-B

The present study was undertaken to establish *(a)* whether the initial orientation has a significant effect on the stress-strain curves of zinc and magnesium sheared at room temperature, and *(b)* whether the c/a ratio in hexagonal metals has a significant effect on the anistropy of strain hardening. This ratio is 1.8560 for zinc and 1.6240 for magnesium compared with the ideal ratio for close packing of spheres, 1.633.

Single crystal specimens of magnesium and zinc, ½ in. in diameter, were tested in a modified Bausch-type shear apparatus equipped with provision for readily altering the direction of loading through rotation of the crystal in the grips. The crystals were loaded at a rate of 6.0×10^{-3} lb. per sec. Tests on several specimens each of zinc and magnesium, all of different orientations, showed that the resolved shear-stress versus shear-strain curves were independent of initial orientation and were completely recoverable by annealing (at 350° C. for 2 hr. with zinc and at 400° C. for 1 hr. with magnesium).

Additional experiments with magnesium disclosed that the c/a ratio has no significant effect on the deformational behavior of hexagonal metals with respect to the anistropy of strain hardening. It was found that magnesium behaves in close accord with zinc as reported in earlier work, in that *(a)* the latent slip systems at 60 and 120° to the active slip direction are hardened more than the active slip direction; *(b)* the hardening is the same for 60 and 120° rotations and increases in proportion to prior strain; *(c)* when the direction of shear is reversed, plastic flow begins at a lower stress than the stress at which strain was discontinued and there is a permanent loss in strain hardening; and *(d)* both the lowering of the flow stress and the permanent loss in strain hardening are proportional to prior strain.

In the present tests on magnesium, an increase in shear stress was found to be additive when the direction of shear was rotated 60 or 120° and then returned to the original slip direction. On cycling at 180°, the flow stress decreased significantly for the first rotation and less significantly for the second and subsequent rotations. As in earlier work on zinc,



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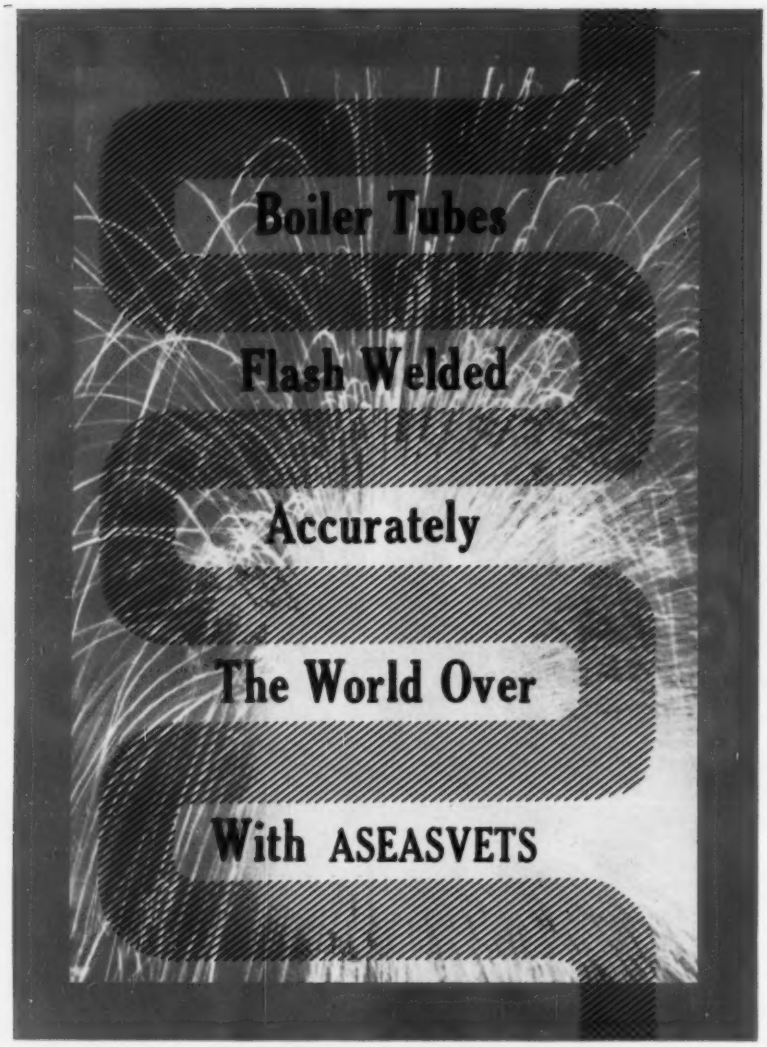

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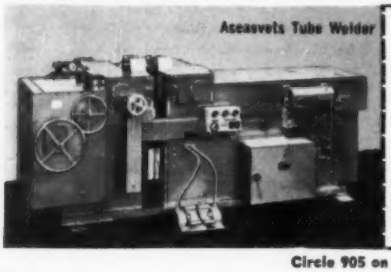
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Circle 905 on Page 48-B

Deforming Crystals . . .

it was observed that some slip lines apparently unslipped when the direction of shear was reversed. However, for the second and subsequent reversals, there was comparatively little unslipping of slip lines.

Further tests on magnesium crystals showed that it is impossible to induce prism and pyramidal slip in magnesium by direct shear at room temperature.

The existence of the relatively large Bauschinger effect in magnesium may be explained by a discoloration mechanism involving the piling up of dislocations against obstacles on initial leading, and the entrapment of these dislocations within energy wells of the stress field of the dislocation structure upon release of the applied stress. When stress reversal occurs, these piled up dislocations are then able to move at a lower stress than that at which strain had been discontinued, resulting in significant plastic flow. This line of reasoning may be extended to an explanation of the behavior upon continued cyclic stressing.

In conclusion, there appears to be complete agreement between the behavior of zinc and magnesium in regard to anistropy of hardening in direct shear.

L. J. Demer

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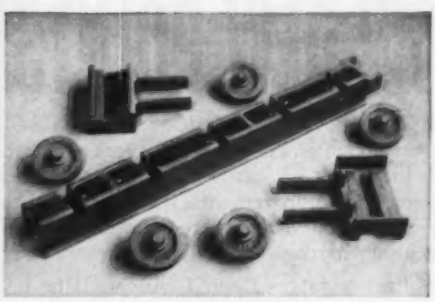

Note

As a point of interest, all of the castings shown here were produced for Lindberg Engineering Company, Chicago, for incorporation in heat-treating and annealing equipment sold by that company. The centrifugally cast tube for the generator, trays, and rollers for the furnace rails are cast of HOM. The rails and rail supports for the furnace are statically cast of 35-15 alloy.

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Circle 986 on Page 48-8

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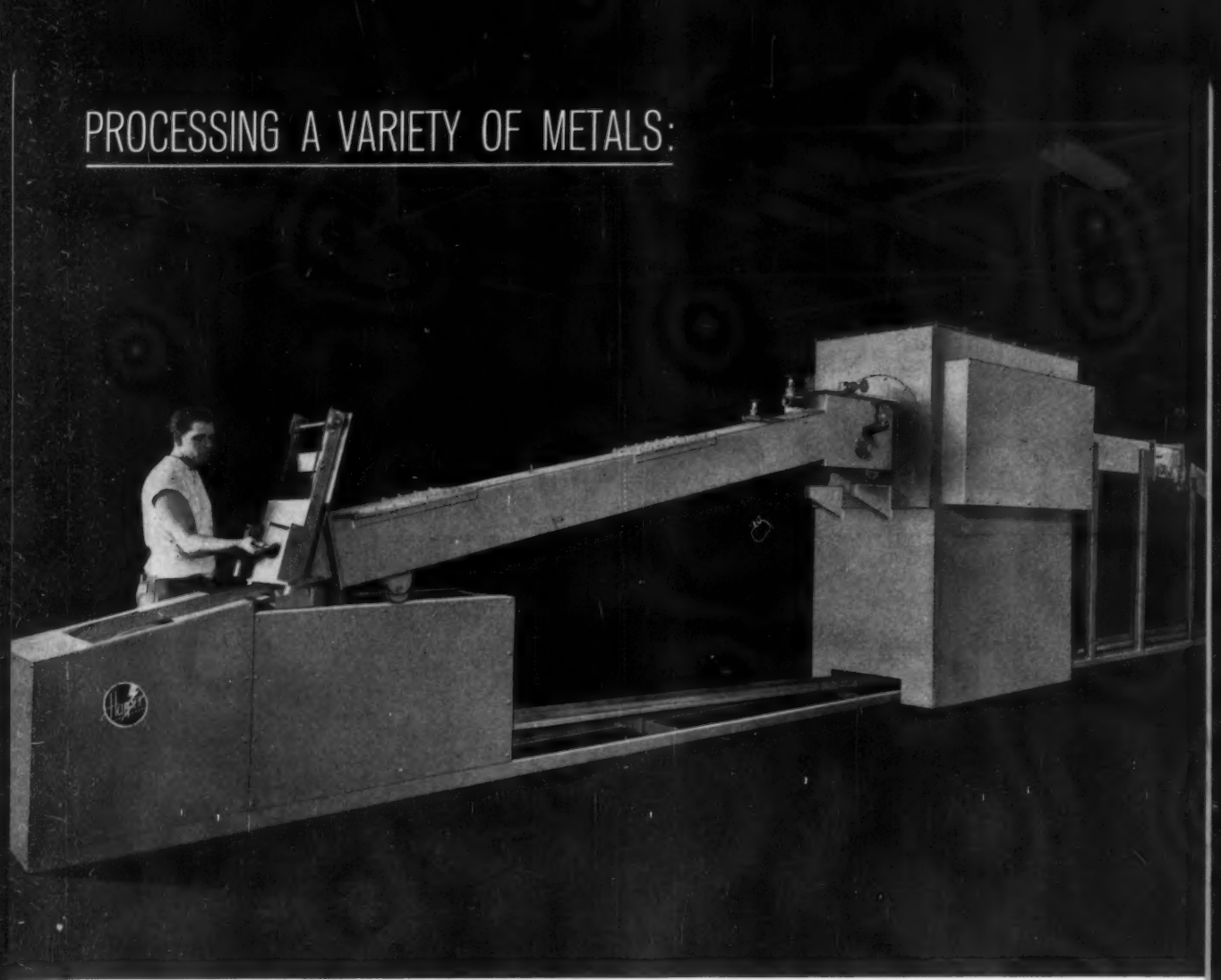

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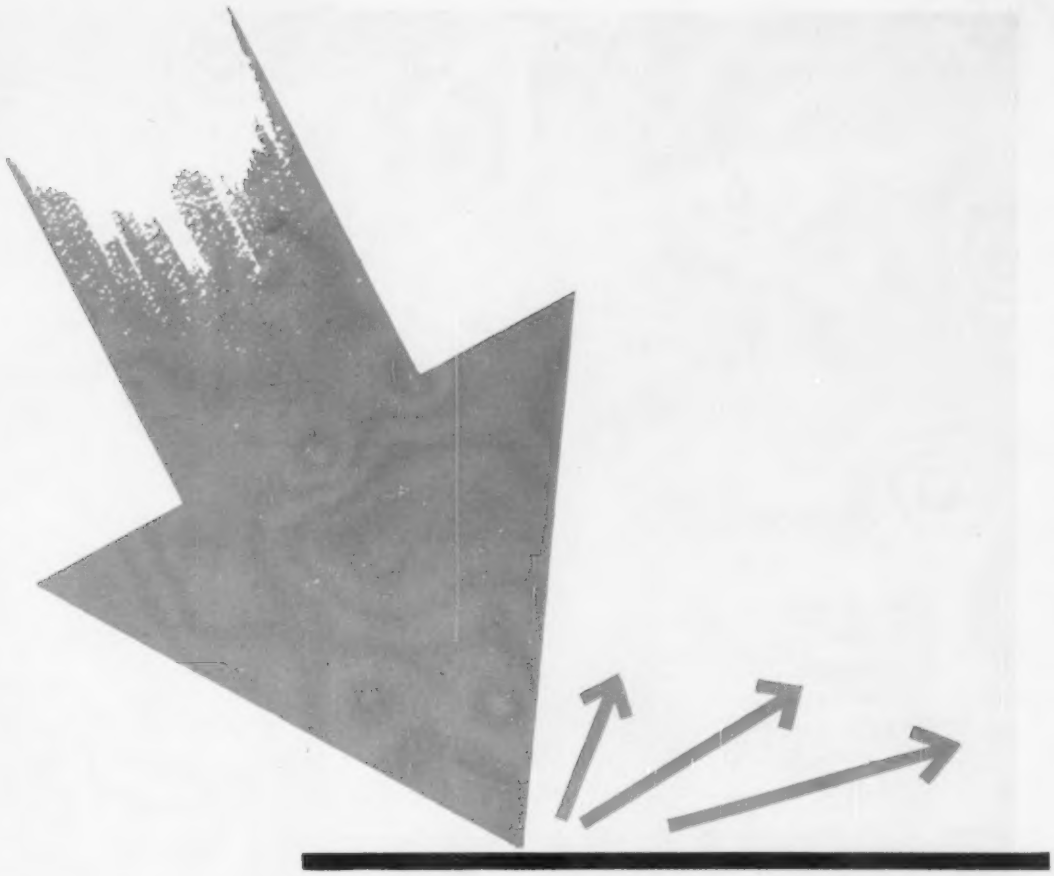
Circle 907 on Page 48-B



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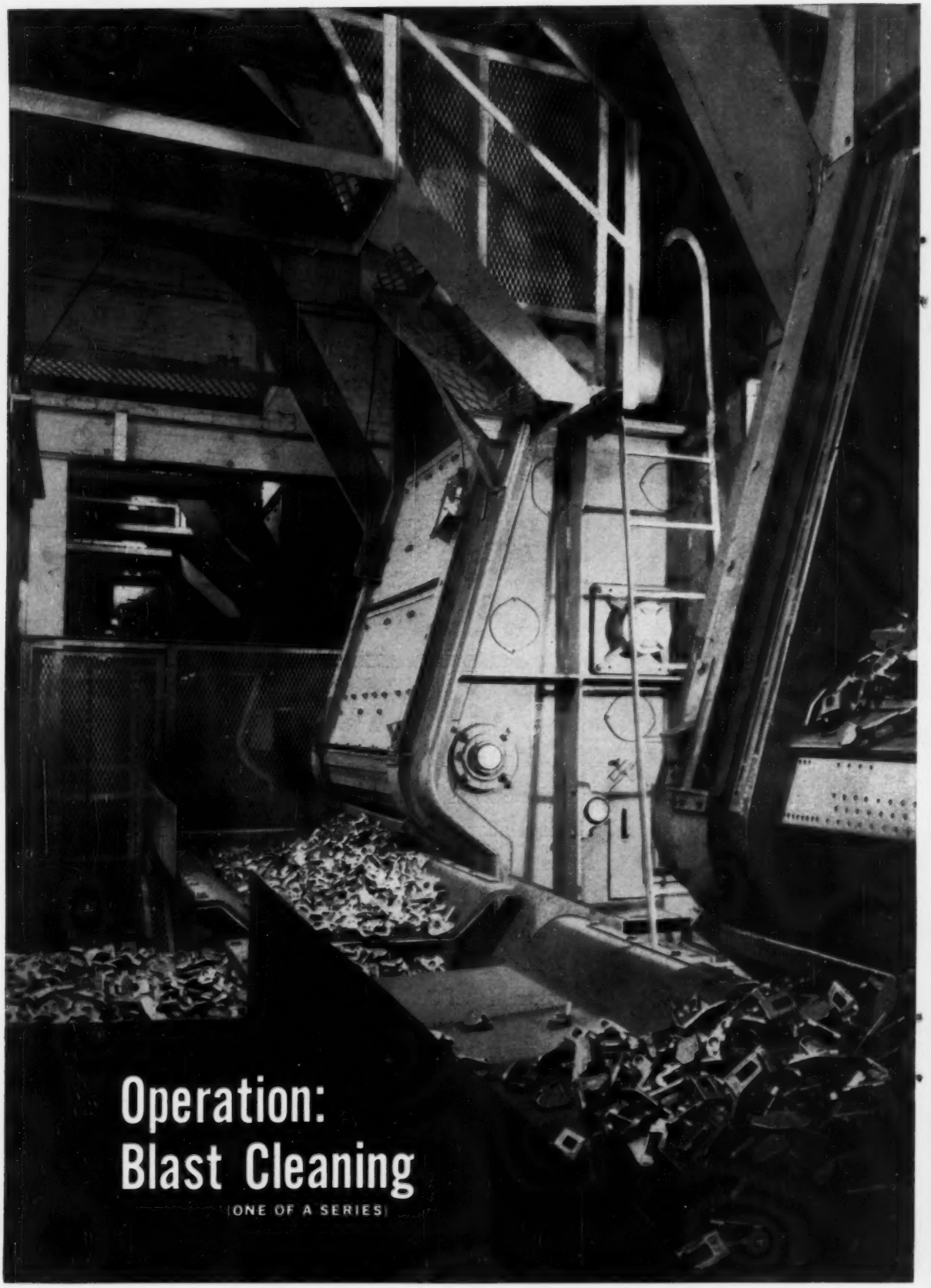
HELPING INDUSTRY CHOOSE STEELS THAT FIT THE JOB

Circle 908 on Page 48-S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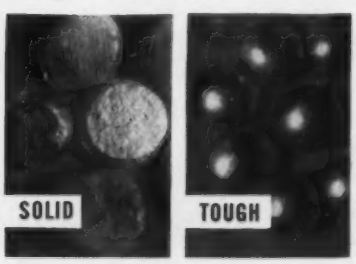

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Circle 909 on Page 48-S

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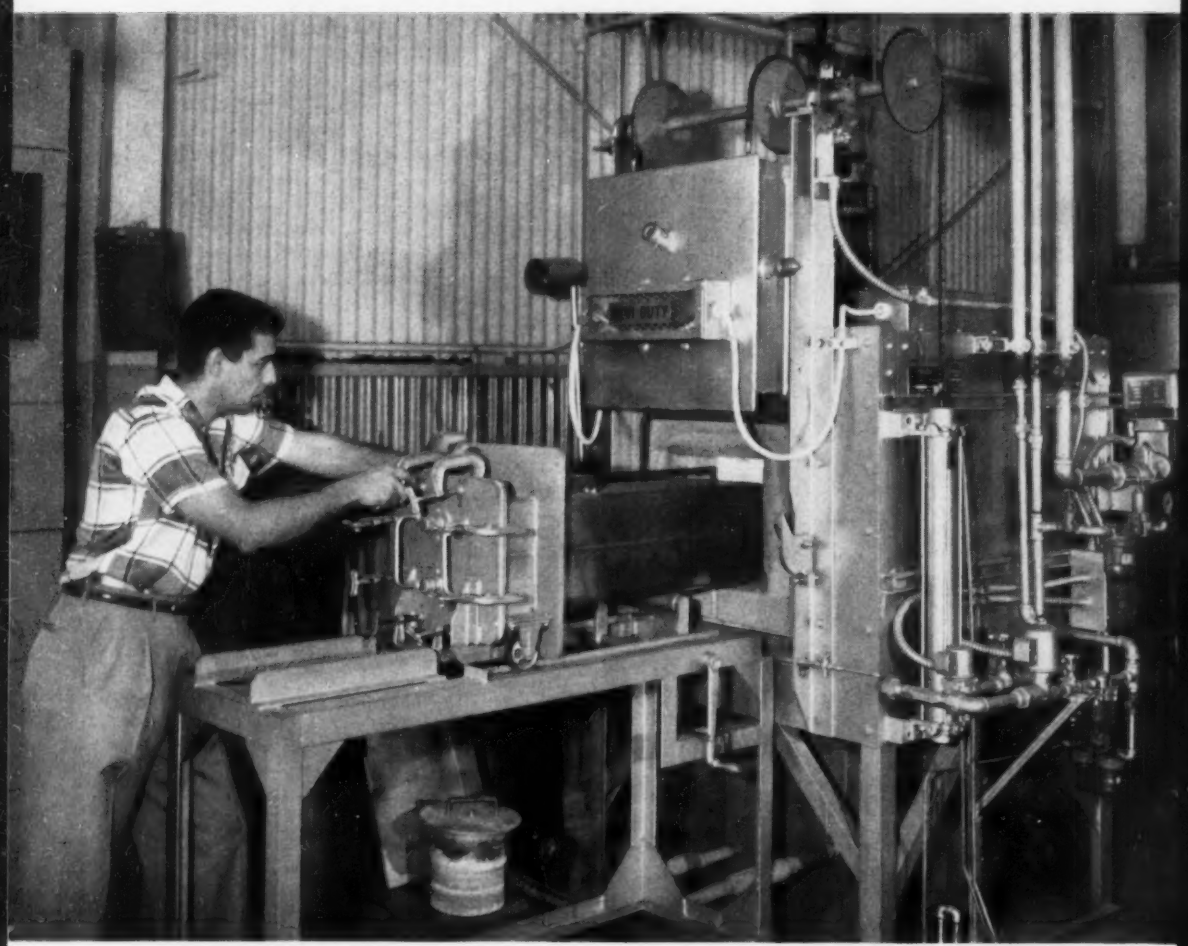

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Circle 910 on Page 48-B

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Circle No. 1 on Page 48-B

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Circle No. 3 on Page 48-B

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Write for Catalog RT-58 for details on Wilson "Brale" Penetrators plus the complete line of Wilson Rockwell hardness testers.

WILSON "ROCKWELL" HARDNESS TESTERS

Wilson Mechanical Instrument Division

ACCO

American Chain & Cable Company, Inc.

230-F Park Avenue, New York 17, N. Y.

Circle No. 5 on Page 48-B

TEST WIRE, FOIL ...FAST...AT LOWEST COST!

VERSATILITY and ECONOMY are key features of the Scott Model CRE Electronic Tester. You get ultra-high accuracy of inertialess electronic weighing . . . plus effortless, error-free, push-button testing. Stress-strain data "picturized" on strip chart. Ample magnification for detailed analyses. Interchangeable test capacities to 1000 lbs. For facts on Model CRE Tester, write **Scott Testers, Inc., Blackstone St., Providence, R. I. Tel: DExter 1-5650 (Area Code 401).**

SCOTT TESTERS

THE SURE TEST...SCOTT!

Circle No. 6 on Page 48-B

Solve

Inspection Sorting Demagnetizing *Problems*

with

MAGNETIC ANALYSIS...

MULTI-METHOD EQUIPMENT

Electronic equipment for non-destructive production inspection of steel bars, wire rod, and tubing. Detects mechanical faults and variations in composition and physical properties. Average inspection speed — 120 ft. per minute.

MULTI & SINGLE FREQUENCY EQUIPMENT

Eddy current equipment for non-destructive testing of non-magnetic metal tubing, bars, wire, 1/8" to 3" dia. at test speeds from 200 to 600 fpm. Multi-frequency unit offers 6 simultaneous inspection methods to indicate surface and subsurface flaws, or variations in mechanical, physical, and metallurgical properties. The single frequency unit offers one inspection method to indicate flaws only.

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Electronic equipment for inspecting ferromagnetic wire ropes from 1/32" to 3" diameter. Detects broken, cross-over or missing wires, plus defective welds and deformations at production speeds up to several hundred feet per minute.

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Electronic instruments for production sorting of both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

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Electrical equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

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Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

"THE TEST TELLS"

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MAGNETIC ANALYSIS CORP.

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Circle No. 7 on Page 48-B

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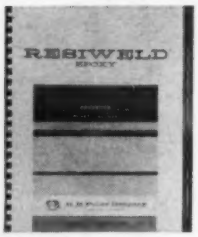

Interested in modernizing your production? Get this handy reference guide on epoxy adhesives, coatings, sealants, and plastic alloys . . . without cost or obligation.

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Circle No. 8 on Page 48-B

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OVER 40,000 IN USE

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90-35M Van Wyck Exp., Jamaica 35, N.Y.

Circle No. 9 on Page 48-B

MULTI MOTION DIES* ....
FOR COMPACTING POWDERED MATERIAL TEST SPECIMENS ....

DL-1001
TENSILE TEST BAR
MPA STANDARD
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- Tensile Bars
- Transverse Bars
- Green Strength
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- Slugs
- Stepped Parts

Complete design facilities for dies or subpress units to press unusual shapes in lab presses.

*PATENTED

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Send for stock die catalog or send rough sketches for help with your design.

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Circle No. 11 on Page 48-B

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SAVES THE GOLD YOU NOW LOSE
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STuart 1-6100

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Circle No. 12 on Page 48-B

THE NEW
DERMITRON
NON-DESTRUCTIVE COATING THICKNESS TESTER

FAST... ACCURATE NON-DESTRUCTIVE DIRECT-READING

- Instantly measures the thickness of metallic and non-metallic coatings and films
- Based on eddy-current principles
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This portable instrument for both laboratory and production use, gives fast, accurate and direct readings of virtually any coating on any base, including:

- Metal coatings (such as plating) on metal base (magnetic and non-magnetic)
- Non-metallic coatings (such as paint, anodizing, hard-coat, ceramic) on metal base
- Metal films (such as vacuum metalizing) on non-metallic base (plastics, ceramics)

Write for latest bulletins and questionnaire to help solve your thickness testing problems

UNIT PROCESS ASSEMBLIES, INC. UPA

Circle No. 13 on Page 48-B

Whitelight MAGNESIUM

your comprehensive independent mill source of magnesium alloy . .

ALLOYS
AZ10
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RODS ¼" dia. to 6½" dia.
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SOLID SHAPES .022" min. to 6½" circle
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Circle No. 14 on Page 48-B

TENSILKUT®

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Other Patents Pend.
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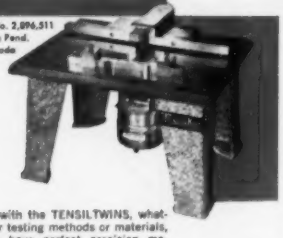

● Now with the TENSILTWINS, whatever your testing methods or materials, you can have perfect precision machined physical test specimens in less than two minutes.

● TENSILKUT precision machines all foil, film, sheet and plate metals . . from .0005" foil to .500" plate. Hard .001 stainless steel foil to soft ½" aluminum, soft plastic film 1 mil in thickness or the abrasive glass laminates in .500" plate, are machined with specimen configurations accurate to ± .0005". Machined edges are completely free of cold working or heat distortion and require no hand finishing.

● TENSILKUT table and floor models are available with motors from ½ to 2½ h.p. Write for free brochure.

TENSILGRIND©

● TENSILGRIND precision grinds physical test specimens from high alloy refractory metals and hardened sheet and plate metals to RC 65.

● The test samples are precision ground by a series of light passes of the metal against a 7 inch diameter contoured grinding wheel. The matched master templates accurately control the specimen configurations to ±.0005" and are interchangeable with TENSILKUT templates.

● TENSILGRIND is mounted on a metal cabinet and includes a totally enclosed ½ HP motor, micrometer adjustments, built in radial diamond wheel dresser, and solenoid controlled misting system to insure cool grinding of test specimen edges.

Write for descriptive literature.

SIEBURG INDUSTRIES INCORPORATED
Danbury Industrial Park, Danbury, Connecticut

Circle No. 15 on Page 48-B

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ULTRA-LOW TEMPERATURE CABINETS

for
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- Testing

Seven styles...chest capacities from 1.5 to 6 cu. ft. Uprights up to 22 cu. ft. Temperatures to —140° are controllable within 1°. Immediate delivery.

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Industrial Products Div.
REVCO INC.
Deerfield, Michigan
Setting Trends in Refrigeration Since 1938

Circle No. 16 on Page 48-B

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SINCE 1922

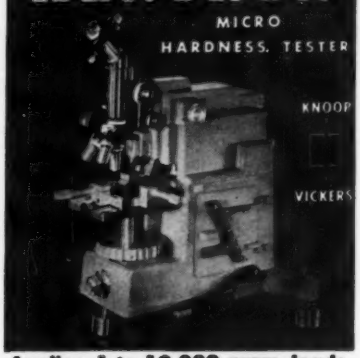
Aluminum and Zinc

THE HOOVER COMPANY
Die Castings Division
North Canton, Ohio
In Canada—Hamilton, Ontario

Circle No. 17 on Page 48-B

KENTRON

MICRO HARDNESS TESTER



Applies 1 to 10,000 gram loads

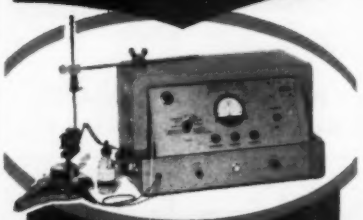
Write for Bulletin

Kent Cliff Laboratories Div.
The Torsion Balance Company
CLIFTON NEW JERSEY

Circle No. 18 on Page 48-B

TESTING PLATING THICKNESS?

15 Day FREE Trial
Guarantees Satisfaction



KOCOUR ELECTRONIC THICKNESS TESTER MODEL 955

Model 955 determines the thickness of decorative and heavy chromium, silver, tin, cadmium, zinc, brass, copper, nickel, lead, and other metallic deposits on various base metals. 90 - 95% accurate . . . Direct reading . . . simple operation.

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Circle No. 36 on Page 48-B

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Circle No. 19 on Page 48-B

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Circle No. 20 on Page 48-B

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HELPS PRODUCE ANOTHER NEW PRODUCT

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Circle No. 21 on Page 48-B

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Circle No. 22 on Page 48-B

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(detect certain defects, too!)

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Sorts automatically—and non-destructively — accidentally mixed or incorrectly processed metal parts by their metallurgical characteristics; Analysis, Structure, Heat treatment, Hardness, etc. Detects certain types of cracks and defects.

Leading industrials everywhere use the CYCLOGRAPH as a quality control inspection instrument or for salvage operations. Write for complete details.

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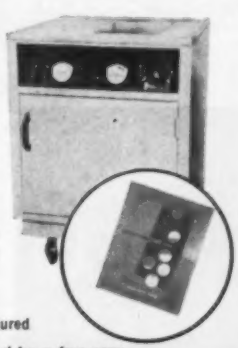
COMPANY
ENGLEWOOD 3, NEW JERSEY

In Canada: Tatnall Measuring & Nuclear Systems, Toronto

Circle No. 23 on Page 48-B

New

ROLL-AROUND ULTRASONIC CLEANERS



These roll-around ultrasonic cleaning units, of 2-13 gallon capacities, consist of generator, transducer and counter top and are easily moved on large casters. Tanks, with bottom transducer coverage from 27-50%, are positioned off-center to provide a work area for baskets.
To operate, simply plug into a 115 volt line. No connection to drain or plumbing is required since the cleaners are drained by means of a flexible hose. Optional features include 2-5 micron filter and heating elements which maintain temperatures from ambient to 180°F.
Units can be used with solvents, detergents, mild acids and alkaline cleaners.

Roll-around ultrasonic cleaners are among the many units featured in National Ultrasonic Corporation's new 32-page Ultrasonic Cleaning Equipment Catalog 60. Write on your company letterhead for a free copy.

NATIONAL ULTRASONIC CORP.

111 Montgomery Ave., Irvington 11, N. J.
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Circle No. 24 on Page 48-B

FREE

the QUENZINE STORY

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. . . . when quenched in Beacon Quenching Oils with QUENZINE added.

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CUTTING OIL

best for all

Machining Operations including Threading, Tapping and Broaching

1 - Higher load-carrying capacity
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3 - Closer tolerance through better cooling
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5 - Finer finish

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ALDRIDGE INDUSTRIAL OILS, INC.
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Circle No. 25 on Page 48-B

the GENUINE BRINELL

HARDNESS TESTING MACHINES made by the Alpha Co. of Sweden and available from our stock at New Rochelle

Never approached in ACCURACY AND CONSTANCY of calibration . . . at the standard 3000kg test load . . . maximum error plus or minus 2½ kg

Write for Bulletin No. A-18

GRIES INDUSTRIES, INC.
Testing Machines Division
NEW ROCHELLE 3, N. Y.

Circle No. 29 on Page 48-B

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— ASSEMBLIES —
METAL PARTS FABRICATION

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Over 40,000 Sq. Ft. of Manufacturing Area. 42 Presses from 5 to 200 Ton. Deep Drawing—Spinning—Thread Rolling. Welding—Riveting—Soldering. Dip & Spray Painting—Bake Ovens. Electroplating—Etching—Embossing. Tool & Die Making—Precision Machining. Electrical and Mechanical Assembly. Design—Development Facilities. Complete line of Inspection & Test Equipment.

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Circle No. 27 on Page 48-B

- CLAMPS, JAWS & BASE PLATE ARE ELIMINATED
- NO CONVERSIONS OR CALCULATIONS
- TEST ANY SIZE, SHAPE OR TYPE METAL
- NO SKILL REQUIRED
- SCALE READINGS IN ROCKWELL & BRINELL
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Many thousands used by industry and government. Write, wire or call for additional details and prices.

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Circle No. 28 on Page 48-B

Distortion in Tool Steels

By Dr. B. S. Lement

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173 pages $10.00 per copy

Published, 1960

American Society for Metals
Metals Park, Novelty, Ohio

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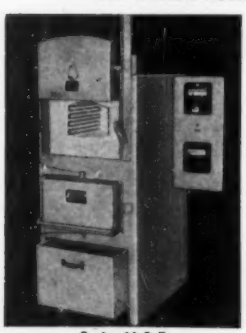
Combination Models—Series H and D

Hardening Range ..... 2000° F and 2300° F
Drawing Range ..... 800° F and 1250° F
Four Standard Models ..... or special design to suit



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Ten models 2000° F and 2300° F range

All standard models include an automatic indicating controller and are wired ready to operate on standard line voltage. *Write for bulletins A-59 and B-59.*

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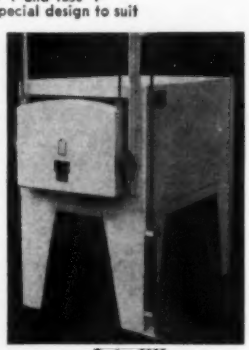

Series 2000

ELECTRA PRODUCTS CO. **Montgomeryville, Pa.**

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METALLOGRAPHIC SAMPLES POLISHED DAILY WITH

DISA - ELECTROPOL

- Quick exchange of electrolytes
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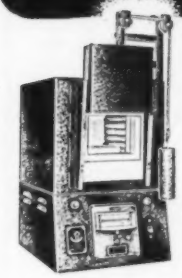
Circle No. 31 on Page 48-B

HUPPERT ELECTRIC FURNACES AND OVENS
for Laboratory and Plant



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- Range: 300°F. to 2000°F.
- High temperature, heavy-duty Kanthal elements
- Multi-insulation
- Counter-weighted, tight-sealing door
- Operational pilot light
- Shipped ready to operate

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28 Standard Sizes

- Continuous operation to 1850°F.—intermittent to 1950°F.—for 2300°F. on special order.
- Complete with automatic electronic controller.
- Tight-sealing, wedge-type door.
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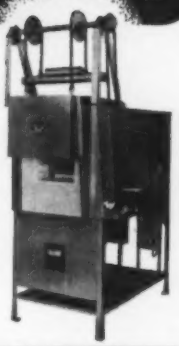
Shipped Ready to Operate
Model No. 16 Illustrated $1050.00



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Request new catalog on furnaces, ovens, data, prices.

Circle No. 32 on Page 48-B

How to Cut Pot Costs:

Buy low-cost Eclipse pressed (not welded) steel pots . . . and replace them on a regular schedule.

1 Lower initial cost
2 Elimination of failures
3 Faster, more even heating
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Guaranteed free from defects. Write:
Eclipse Fuel Engineering Company
Industrial Combustion Division
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Eclipse PRESSED STEEL POTS

Circle No. 33 on Page 48-B

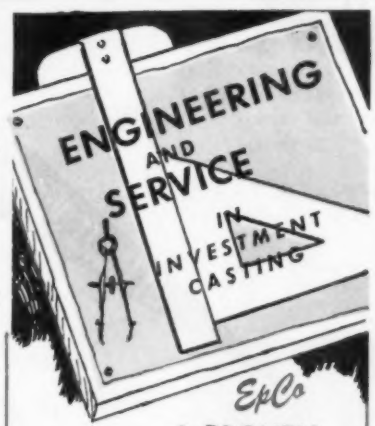
Powder Metallurgy in Nuclear Engineering

- Preparation of powder metals for reactors
- Powder metallurgy of zirconium, beryllium, uranium
- Safe handling of radioactive powders
- New methods, including rolling of powders

This book, which was organized by H. H. Hausner, describes work sponsored by the U. S. Atomic Energy Commission.

275 pages, Price, $10.00

American Society for Metals
Metals Park, Novelty, Ohio



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INVAR CASTING Special Feature—Nickel content held to 35% minimum — 36% maximum

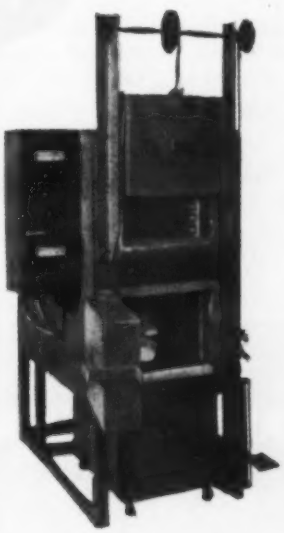
STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.

ENGINEERED PRECISION CASTING CO.

MORGANVILLE, N. J.

Circle No. 34 on Page 48-B

LUCIFER "SPACE-SAVER" COMBINATION HEAT TREATING FURNACES



Two series (8012 and 8008) of "space-saver" combination heat treating furnaces are produced by Lucifer Furnaces, Inc. Hardening, drawing or preheating, and quenching operations can be performed with one furnace. Each furnace has separate controls permitting independent operation of each unit. The 8012 series chambers operate at 2300, 2000 and 1250° F.; while the 8008 series chambers reach 2300, 2000, and 800° F. The furnaces operate on standard line voltage . . . no transformer necessary. Twenty standard low-cost models are available and each is a complete unit . . . just connect to power supply.

For information about the "space-savers", our complete line, or free engineering advice, call on . . .

LUCIFER FURNACES, INC.
Neshaminy 7, Pennsylvania
Diamond 3-0411

Circle No. 35 on Page 48-B

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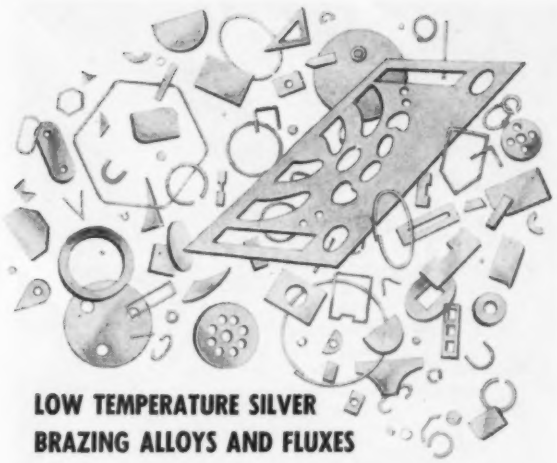

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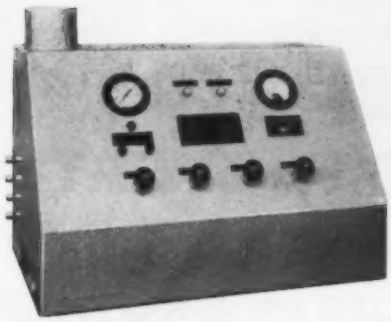

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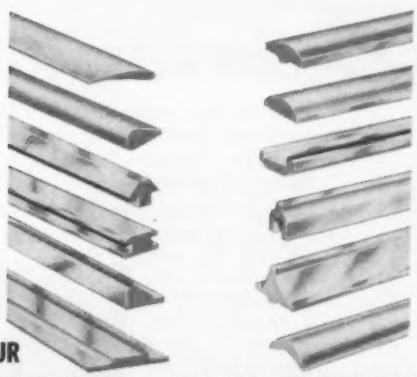

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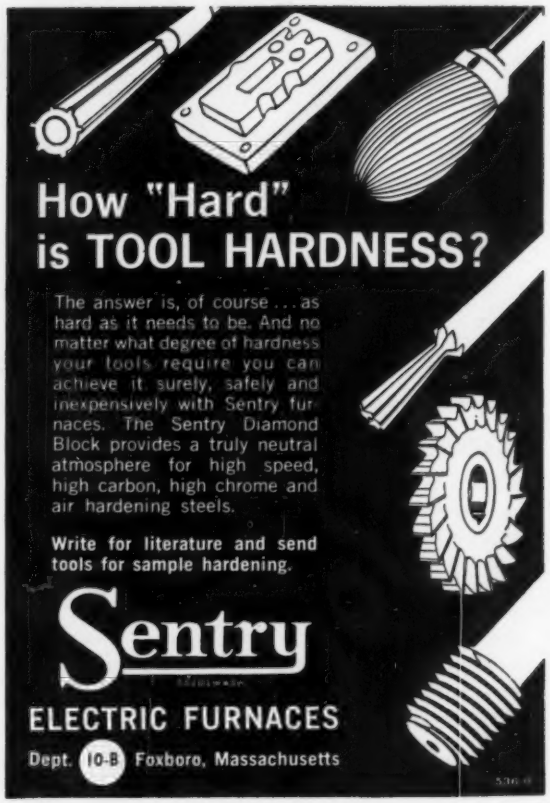

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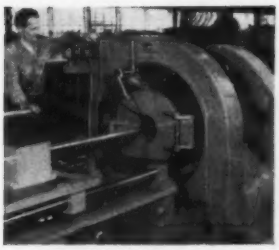

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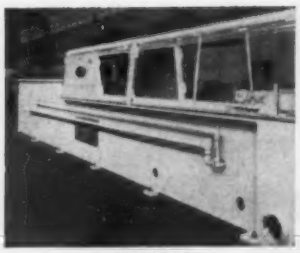

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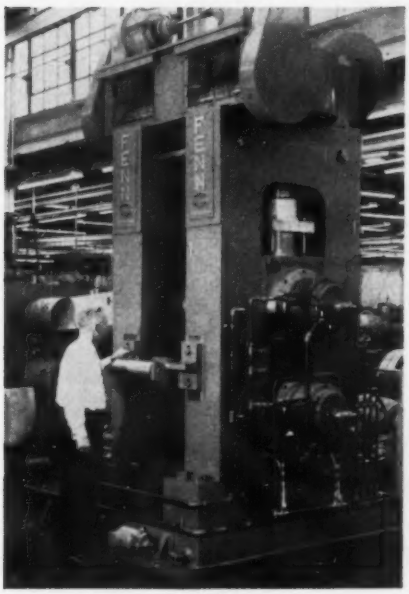

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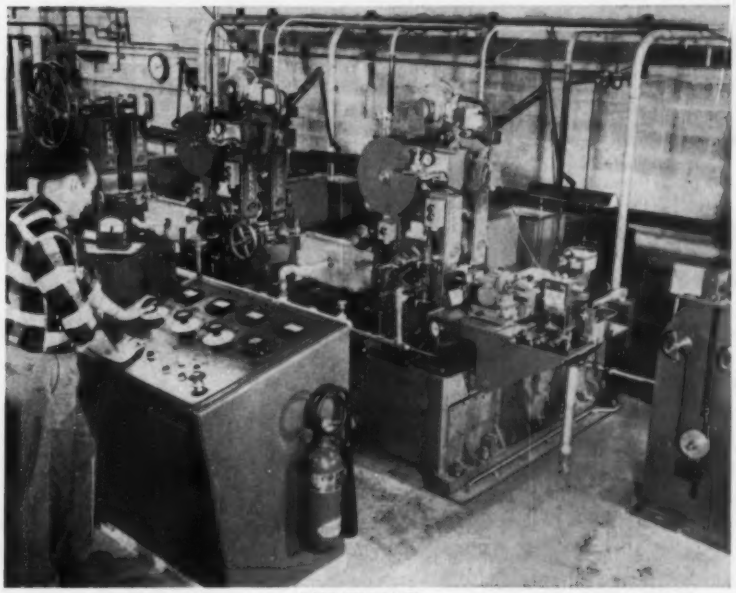

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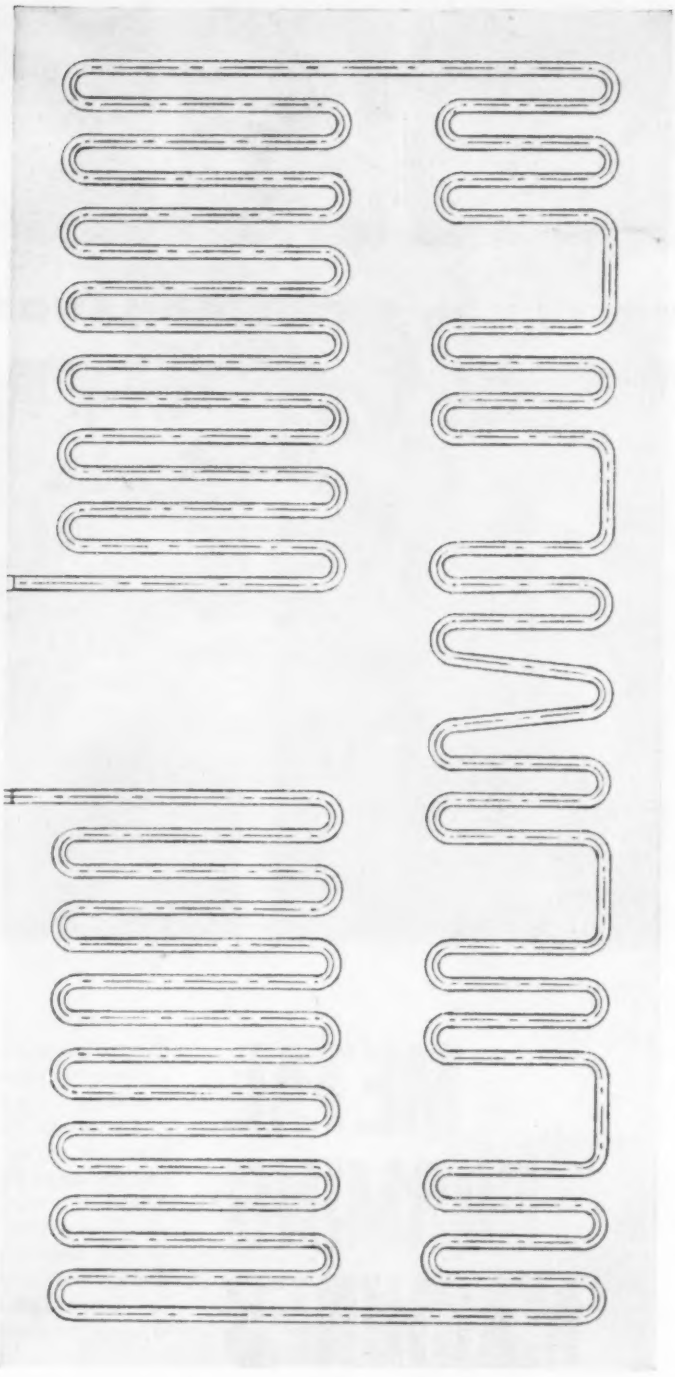

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Circle 916 on Page 48-B

THE LITHIUM REACTOR

CURRENT INFORMATION ON LITHIUM CHEMISTRY AND METALLURGY

TROUBLE SHOOTING COPPER MELTS WITH LITHIUM CARTRIDGES

The addition of lithium in trace amounts to copper results in a number of outstanding improvements. First, it removes oxygen and other dissolved or occluded gases to produce dense copper castings without porosity and with improved conductivity. Secondly, it improves the fluidity of the melt to assure complete filling of intricate molds, easier handling, and fewer inclusions. Thirdly, it improves the grain size of the metal, thereby contributing to better workability and corrosion resistance.

To simplify the use of lithium, LCA developed the "lithium cartridge," a hermetically sealed cylinder of 99.9% pure copper filled with weighed amounts of pure lithium metal. Since the use of the cartridges does not materially alter customary foundry practice or require special equipment, they have found rapid acceptance.

The cartridges are furnished in four different sizes containing, respectively, 2.25, 4.5, 9, and 108 grams of lithium to treat anything from approximately 50 lbs of copper up to about 2400 lbs at one time.

To facilitate immersing the cartridge in the melt, LCA has developed the LCA Lithium Cartridge Applicators. These are essentially graphite rods, bored to hold the appropriate number of cartridges. Applicators are furnished in three models: G-1, G-2 and G-3. Type G-1 handles most required quantities of lithium from 2.25 grams to 40.5 grams. The G-2 can be used for 2.25 grams to 256.5 grams. The G-3 is designed for use with small-quantity experimental melts.

LCA manufactures lithium copper cartridges in a variety of sizes to meet customer requirements.

Lithium Aids Fused Salt Electrowinning and Electrorefining of "Space Age" Metals

In the first half of the 20th Century, fused salt electrolysis had been developed as the chief industrial method for the production of some important metals, such as sodium, aluminum, calcium, and magnesium. The electrowinning of these metals has a number of advantages. Electricity is a low-cost means of reduction . . . high-purity products can be obtained . . . electrolytic methods are amenable to continuous production.

Most of the fused salt baths are based on compositions containing halides of the alkali metals, alkaline earth metals, and the specific metal to be deposited cathodically. The electrolytic production of such metals, as titanium, zirconium, thorium, uranium, molybdenum and beryllium is presently of great interest because of their applications in the field of atomic energy and in jet and rocket craft.

Lithium salts play an important part in the electrolytic production of some of these metals. In many instances lithium chloride is added to improve electrolyte conductance and fluidity and to obtain a low melting salt mixture. For example, the eutectic mixture of lithium chloride and potassium chloride (m.p. 350°C) is often used.

Lithium Corporation of America supplies lithium chloride in anhydrous form for this application.

Recently important work has been done on the electrorefining of beryllium to produce a high-purity product suitable for space and nuclear uses. The anode feed is crude beryllium metal and the bath consists of pure lithium chloride and potassium chloride of eutectic composition. The product deposits in the form of thin, platelike beryllium crystals of a purity comparing favorably with that of high-purity beryllium produced by other methods.

The use of lithium salts is not restricted to these "Space Age" metals, but has also contributed to a recent improvement in the field of aluminum production, where lithium carbonate or fluoride is added to the cryolite-based molten salt electrolyte. These lithium compounds are available from Lithium Corporation of America. Inquiries should be addressed to the Company's New York Office.

LITHIUM IN BRIEF

New developments involving lithium are constantly appearing in the literature. Each month some will be mentioned here briefly.

•

In an investigation of the electrorefining of beryllium, baths studied included $LiCl$-KCl-$BeCl_2$ mixtures. (3758)

•

High-purity cerium metal may be produced by fused salt electrolysis using fluorides of lithium, barium, and cerium. (3780)

•

A recently published report describes a method for determining the solution rate of metals in molten lithium, and covers the effect of additives in stainless steel and impurities in lithium as they bear on corrosion rates. (3882)

•

A new type of miniature electrical cell employs an anode comprised of indium, bismuth, and lithium. (3795)

•

Use of the eutectic mixture of $LiCl$-KCl is advantageous in the electrowinning of titanium. (3954)

•

The preparation of germanium or silicon semiconductors containing lithium is described in a recent patent. (3928)

•

Adherent coatings may be applied to titanium by immersion in aqueous acid fluoride solution containing lithium and ammonium ions. (3768)

•

The corrosion of various materials (pure metals, alloys, carbides) by molten lithium at elevated temperatures (1000-1900°F) was investigated, in both static and dynamic systems. (3907)

•

For further information, write our Technical Service Department, Bessemer City, North Carolina.

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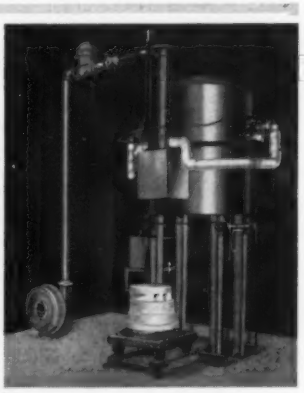

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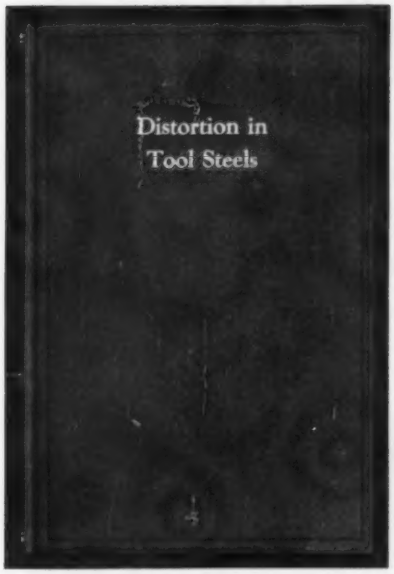
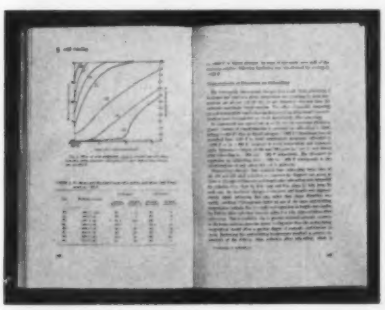
Circle 920 on Page 48-B

DISTORTION IN TOOL STEELS





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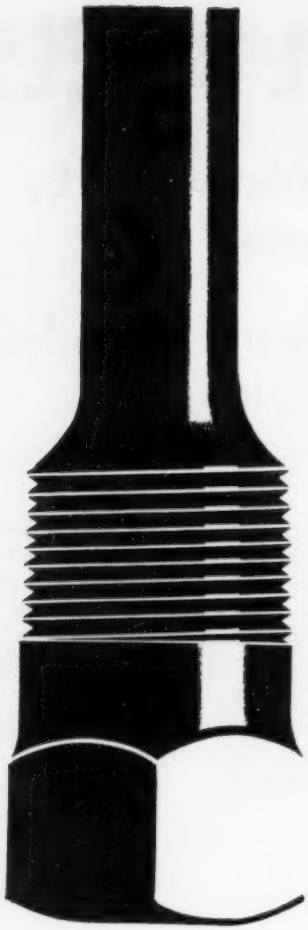

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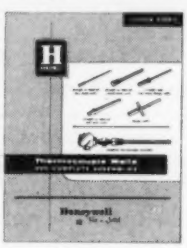

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"Why Nondestructive Testing Is Needed", by Robert C. McMaster (p. 70), is the first of eight projected articles covering various aspects of nondestructive testing which will be published in *Metal Progress* during the coming year. As indicated in the footnote to his article, Dr. McMaster is not only professor of welding engineering at Ohio State University (where he helped develop university and industrial training courses in the nondestructive testing field),

but also editor of the Nondestructive Testing Handbook, prepared by the Society for Nondestructive Testing.

A graduate of Carnegie Institute of Technology (B.S., 1936) and California Institute of Technology (Ph.D., 1944), he worked in the electrical engineering division of Battelle Memorial Institute for nearly ten years before joining the Ohio State faculty in 1955. His attention is now centered on investigations of television fluoroscopy, evaluation of liquid-penetrant materials and nondestructive testing of aircraft honeycomb structures and weldments of complex shapes.

Professor and editor are only two of Bob McMaster's titles – another is TV weatherman. Studies of lightning and the protection of electric power systems from lightning damage led Bob to graduate training in synoptic meteorology, and from there to such activities as precipitation static studies in aircraft and finally a daily weather show, "Understanding Our Ohio Weather", presented over WBNS-TV in Columbus.

Other activities center around his family (his wife Laura, and their three children, Roy, James and Lois) and include boating and

swimming at the family camp at Indian Lake, Ohio, model railroading, and motion picture photography.

He belongs to a long list of technical groups including S.N.T. (he's a past president), A.S.M., A.W.S. and A.S.T.M. and is a member of many technical committees, particularly those concerned with education and other efforts devoted to advancing welding engineering and nondestructive testing. And he still has time to serve various firms as a consultant.

J. B. Seabrook, who discusses the properties of Ni-Al age hardening steel on p. 80, is gear metallurgist at the medium steam turbine, generator and gear department at the Lynn River Works of General Electric Co., West Lynn, Mass. His interest in nitriding and age hardening steels reflects his basic concern: finding the best ways to combine highest wear resistance and fatigue strength with extreme dimensional accuracy. After graduating from Massachusetts Institute of Technology with a B.S. in metallurgy in 1949, he joined the Lynn River Works where he has worked on salt bath heat treating and induction hardening, and on the development of large area germanium rectifiers (he's co-holder of a patent on making P-N junction semiconductor units). More recently he has worked on materials and process development with all types of gearing, especially aircraft and missile gearing.

The techniques evolved by Wyman-Gordon engineers for forging Astroloy, one of the newest superalloys, are described by John Luchok, manager of the vacuum metallurgy department, in his article on p. 91. After graduating from Carnegie Institute of Technology (with a B.S. degree in metallurgical engineering), he worked

for General Electric Co. for a short time, then entered the armed services as a lieutenant in advanced weapons in the Ordnance Corps. After his discharge in 1954, he rejoined G.E. as a research engineer in the metallurgical products department. He has been with Wyman-Gordon since 1958, first as a metallurgist in the research and

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development department and more recently as manager of vacuum metallurgy.

Although his favorite outdoor activity is golf, he has a keen interest in all sports. During his college days, he made the Carnegie Tech varsity football team and played first string halfback for four years.

RA-333, a new high-temperature alloy, is described on p. 97 by John Maxson (below, right), eastern manager for Rolled Alloys, Inc. of Detroit. A graduate of Colgate University with a B.S. in chemistry, his industrial experience includes work in the analytical and manufacturing departments of Solvay Process Div. of Allied

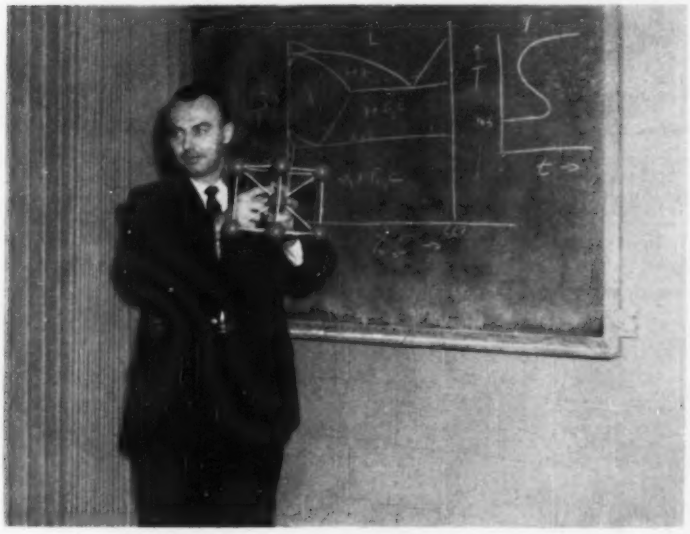
Chemical Corp. and the Bristol Laboratories Div. of Bristol-Myers; he joined Rolled Alloys seven years ago, where his work is concentrated on heat resisting alloys.

Although his job keeps him near the eastern industrial centers (he lives in Mt. Holly, N.J.), he returns to the New York Finger Lakes country whenever he can – his "home town" is Homer (the Homesville of David Harum fame).

The two articles by Bernt A. Ruediger and H. W. Westeren, beginning on p. 101, are based on papers presented at a symposium sponsored by the Industrial Heating Equipment Assoc. in Philadelphia during the National Metal Congress and Exposition. Mr. Westeren, assistant research director for C. I. Hayes, Inc., in Cranston, R.I., is no stranger to *Metal Progress* – an article appeared in February 1960 and a biographical sketch on p. 224 of that issue. Mr. Ruediger, a graduate metallurgical engineer with a M.S. degree, worked as a metallurgist for several years, and then in advance development engineering. He now is concerned with industrial process and product development at General Electric Co.'s Industrial

Heating Dept. in Shelbyville, Ind., as a specialist in market development.

As the photograph below shows, teaching is one of his prime interests – he has prepared and taught several company-sponsored



courses for engineering and marketing personnel covering metallurgy and company products and applications. He is also a member of several panels for industrial conferences.

Married with a family (two boys and a girl), his hobbies include golf, bridge, skiing, fishing, and photography.

The report from Yugoslavia on the production of oxygen-free copper (p. 112) is written by Dragoslav Janicijevic, chief metallurgist of Fabrika Kablova in Svetozarevo. After graduating from the University of Ljubljana in 1952, he became a metallurgical engineer on Fabrika Kablova's staff. He came to the United States in 1953 for a year's training, then returned as chief of the company's oxygen-free copper casting department and was promoted to his present post three years ago. This report came to *Metal Progress* through Manuel Tama, vice-president of Ajax Magnethermic Corp., in Trenton, N.J., who worked closely with Assistant Editor Dermott in preparing the manuscript for publication. The photo of Mr. Janicijevic, by the way, was snapped by Mr. Tama while he was in Yugoslavia last summer.

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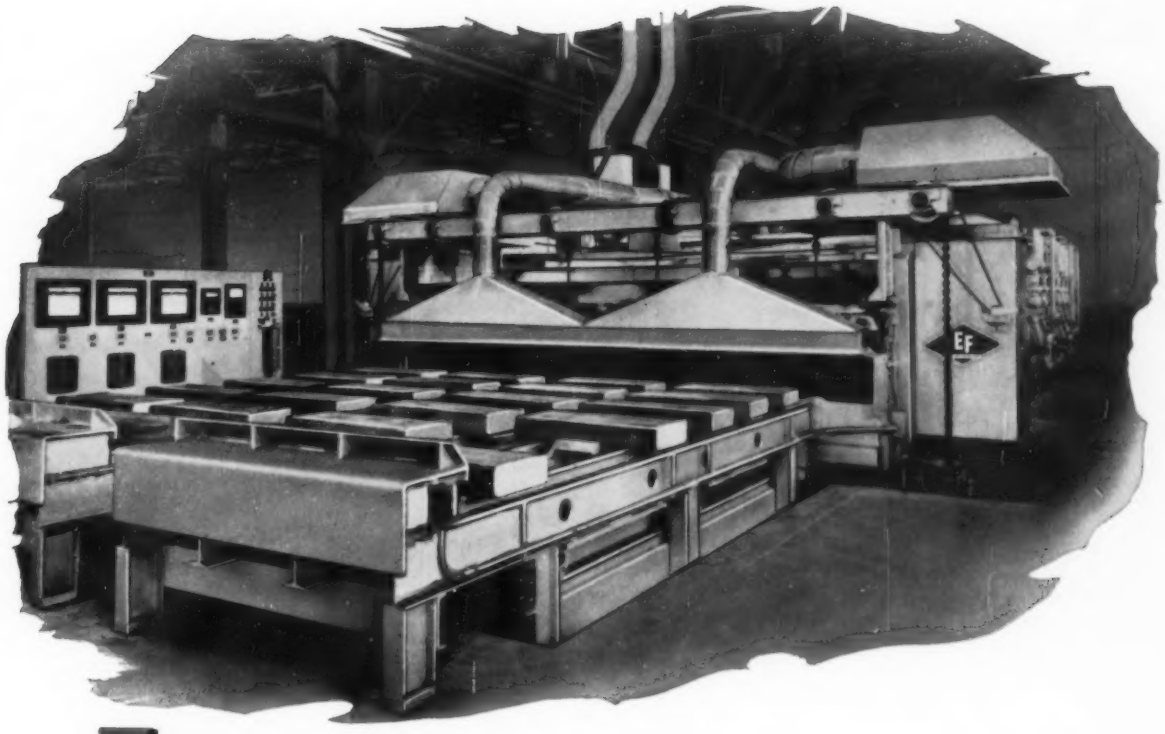

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